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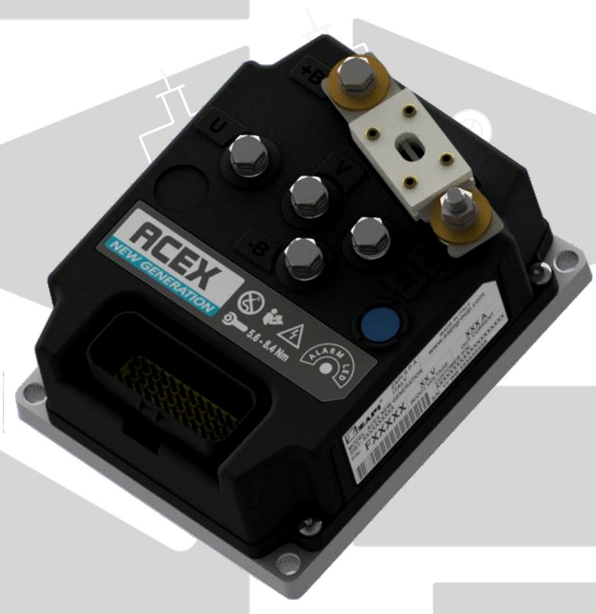
EN

*User Manual*

# ACEX
# NEW GENERATION
## *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 ACEX NEW GENERATION Foc3 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

ACIM ..................AC Induction Motor.
Application..........A customer specific use of Zapi hardware and software.
BLAC..................Brushless AC.
BLDC..................Brushless DC.
CAN....................Controller area network.
ESD....................Electrostatic discharge.
EMC ...................Electromagnetic Compatibility.
EB ......................Electromechanical brake.
EV ......................Electro-valve.
EVP ....................Proportional electro-valve.
FOC....................Field-oriented control.
HW .....................Hardware.
IPMSM ...............Interior Permanent Magnet Synchronous Motor.
LC.......................Line contactor.
LED ....................Light-emitting diode.
MC......................Main contactor.
MCU ...................Micro Controller Unit.
OEM ...................Original equipment manufacturer.
PMSM ................Permanent Magnet Synchronous Motor.
PTC ....................Positive temperature coefficient.
PWM ..................Pulse-width modulation.
SRM ...................Switched Reluctance Motor.
SRPM.................Synchronous Reluctance Permanent Magnet Motor.
SW .....................Software.
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, it 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.***

***This is a further warning within the box. Pay special attention to the annotations pointed out within warning boxes.***

## 1.2 About the controller

### 1.2.1 Operator's safety

The aim of this manual is 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 usage of equipment employing the motor controller have the proper professional skills and knowledge of equipment.

***The high power levels and high torque available from a motor and motor controller combination can cause severe or fatal injury.***

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

***Before doing any operation, ensure that the battery is disconnected and the internal capacitors bank is completely discharged. 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 on 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 inverter for at least 5 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.<br>Design architecture based on CATEGORY 2 according to EN13849; CATEGORY 3 achievable (according to EN13849).<br>Designed to achieve requirements of EN1175-2020 up to PL-d for certain functions (according to EN13849).<br>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

ACEX NEW GENERATION Foc3 inverter is a controller designed to control a single ACIM, PMSM, IPMSM, SRM and SRPM motor, in the range from 1.1 kW to 4.2 kW continuous power, used in a variety of battery-powered material handling trucks.
Typical applications include, but are not limited to: walkie and rider pallet trucks, stackers, low-level order pickers, aerial-lift platforms, small scissor lift, work assist vehicles, small boom lifts, electric scooters and light electric vehicles.

The main inverter features are:

- 16-bits real time signal controller for motor control and main functions.
- 16-bits real time signal controller for safety functions.
- Third generation Zapi field-oriented motor control.
- Smooth low-speed control.
- Zero-speed holding control.
- Zapi patented sensorless and sense-coil control.
- Low-side driver for a line-contactor coil.
- Low-side driver for an electromechanical-brake coil (short circuit protected).
- Drivers for five PWM voltage controlled electrovalves
- A driver for an additional ON/OFF electrovalve.
- Drivers for two proportional valves (PWM current controlled).
- High-side driver for electromechanical-brake and electrovalves with short-circuit and open-load protection.
- Thermal cutback, warnings and automatic shutdown for protection of motor and controller.
- ESD-protected CAN bus interface (IEC/EN 61000-4-2 level 4).
- ESD-protected digital and analog inputs (IEC/EN 61000-4-2 level 4).
- Optional CAN bus protection against overvoltage up to 100 V.
- Software downloadable via serial link (internal connector) or CAN bus (external connector).
- Diagnostic provided via CAN bus using Zapi PC CAN Console.
- Rugged sealed housing and connectors meet 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
Ambient operating temperature range: ...........................................-40 °C ÷ 50 °C
Recommended long term ambient storage temperature range: .......-40 °C ÷ 85 °C
Maximum inverter temperature (at full power): ............................................85 °C
Connector: ..................................................... 35-pins Ampseal, 23-pins Ampseal
Package environmental rating: .........................................................................IP65

## 2.3 Current ratings

| Nominal DC Voltage [V] | Maximum 2-min rated current [Arms] | Continuous rated current [Arms] |
|---|---|---|
| 24 | 240 | 120 |
| | 200 | 100 |
| | 165 | 85 |
| | 120 | 60 |
| | 100 | 50 |
| 36/48 | 210 | 90 |
| | 180 | 85 |
| | 140 | 70 |
| | 80 | 40 |
| 72/80 | 120 | 60 |
| | 80 | 40 |

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

*Custom configurations, featuring current ratings different from those listed above, may be available on request. Please, contact Zapi sales for further information.*

*Internal algorithms automatically reduce the maximum current limit when the controller temperature exceeds 85°C. The temperature is measured internally near the power MOSFETs (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 refer to 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 when it is adequately cooled with its own finned heat sink and 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 | 24 V | 36 V / 48 V | 72 V / 80 V |
|---|---|---|---|
| Conventional working voltage range | 19.2 V ÷ 28.8 V | 28.8 V ÷ 43.2 V<br>38.4 V ÷ 57.6 V | 57.6 V ÷ 86.4 V<br>64 V ÷ 96 V |
| Non-operational overvoltage limits | 35 V | 72.5 V | 115 V |
| Non-operational under-voltage limits | 11 V | 11 V | 30 V |

*By default, at start-up, the controller checks the battery voltage to be within the range from 80% to 120% of the nominal battery voltage. With a different DC voltage than specified, the controller raises an alarm.*

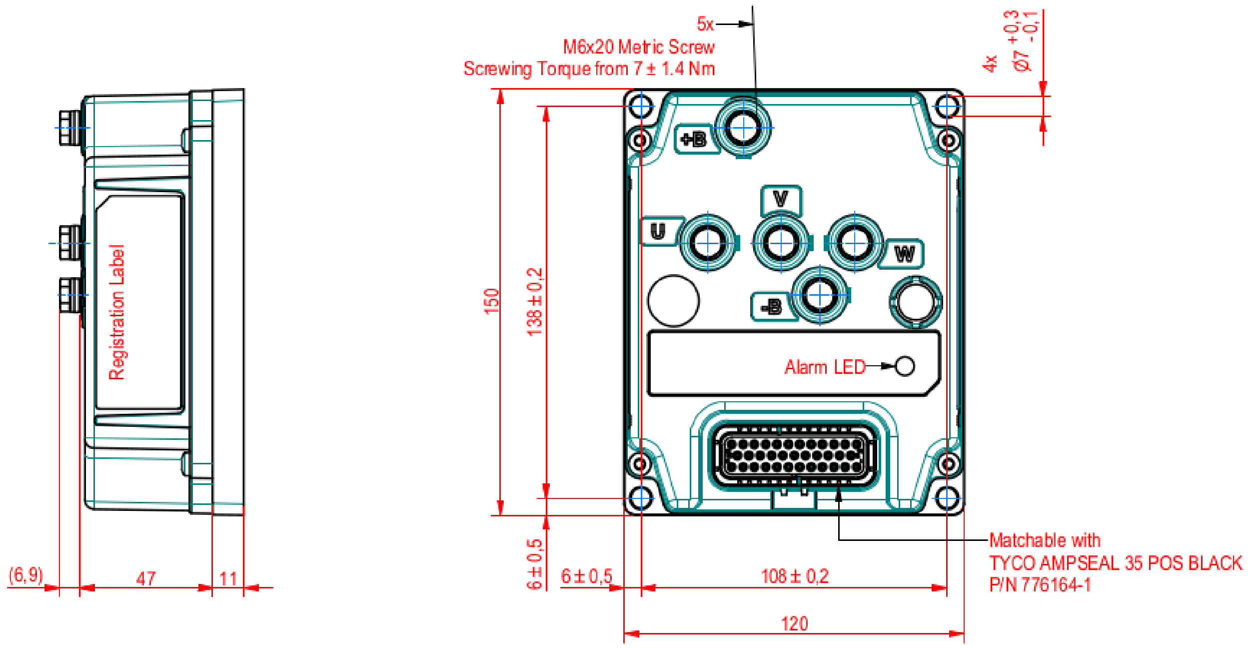
*The working voltage range can be adjusted with two dedicated parameters as described in paragraph 8.2.3. After start-up, the controller is fully operative if the supply voltage stays within this range.*

*Under-voltage is evaluated on the KEY input A10 (A8); overvoltage is evaluated on the positive battery terminal +B.*

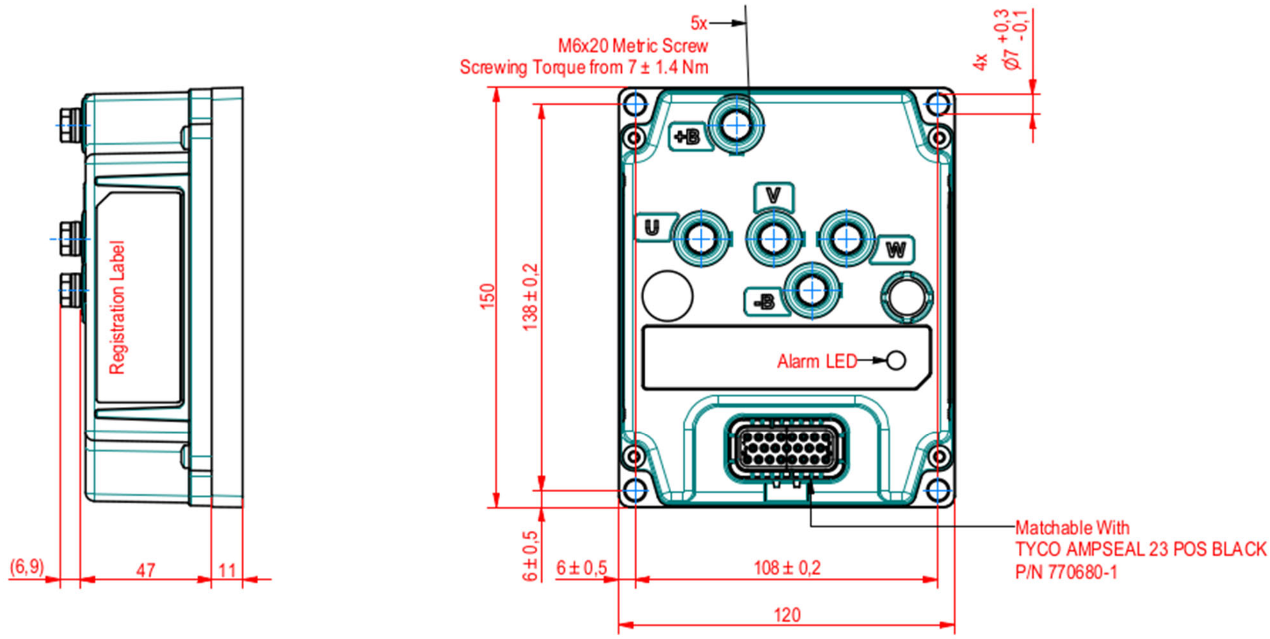
# 3 DRAWINGS

## 3.1 Mechanical drawings

### 3.1.1 Base-plate premium version

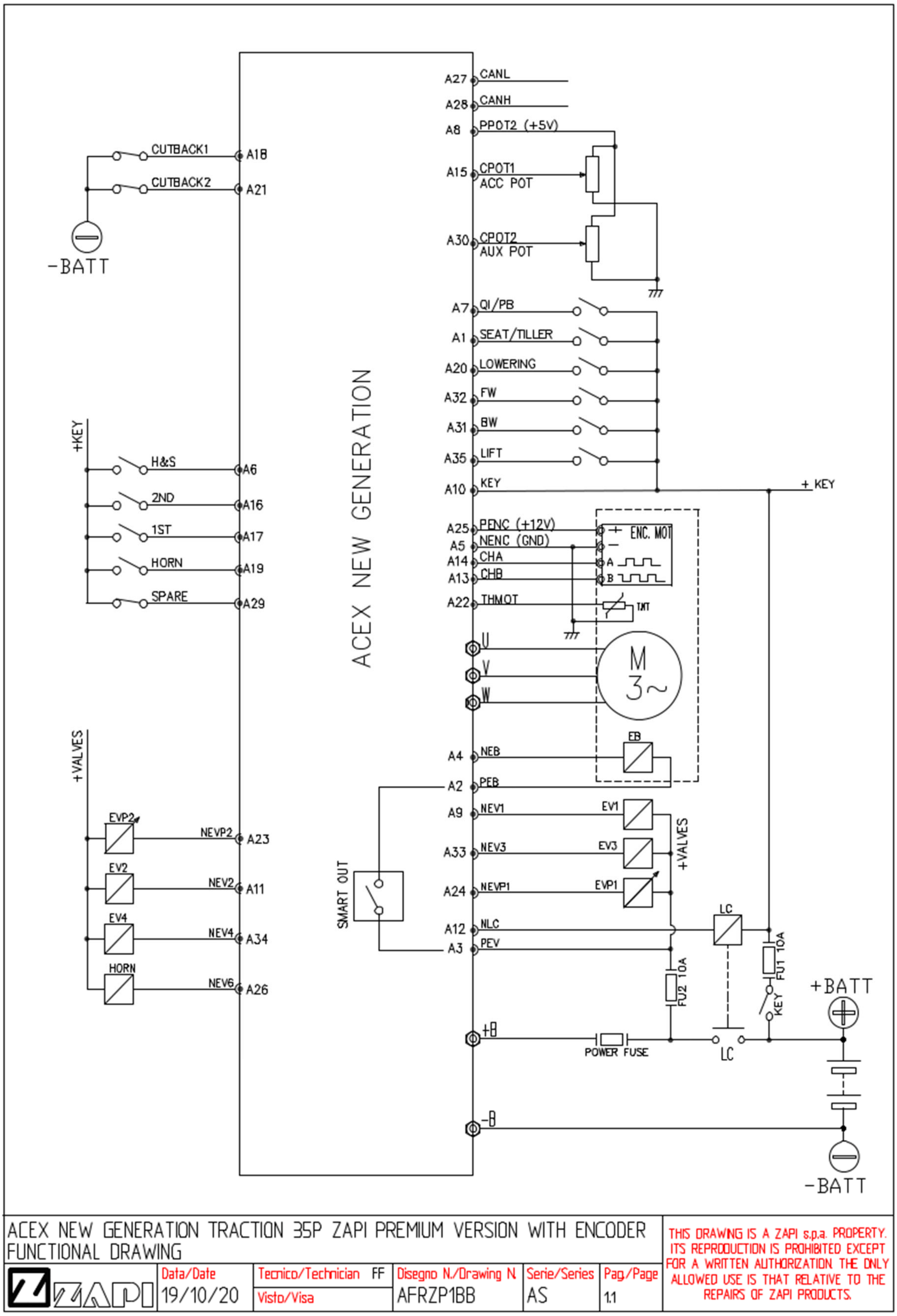



### 3.1.2 Base-plate standard version

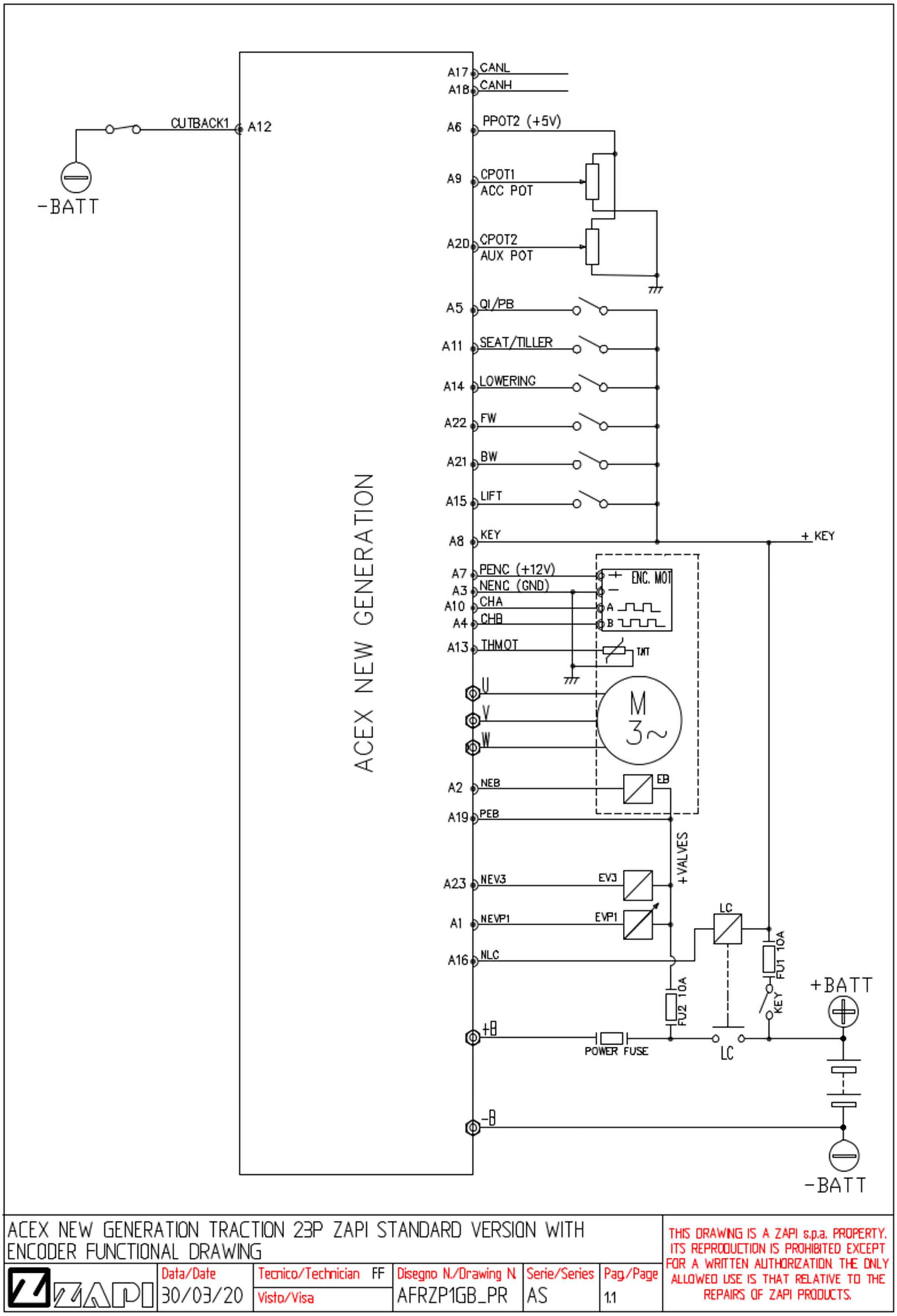


## 3.2 Connection drawings

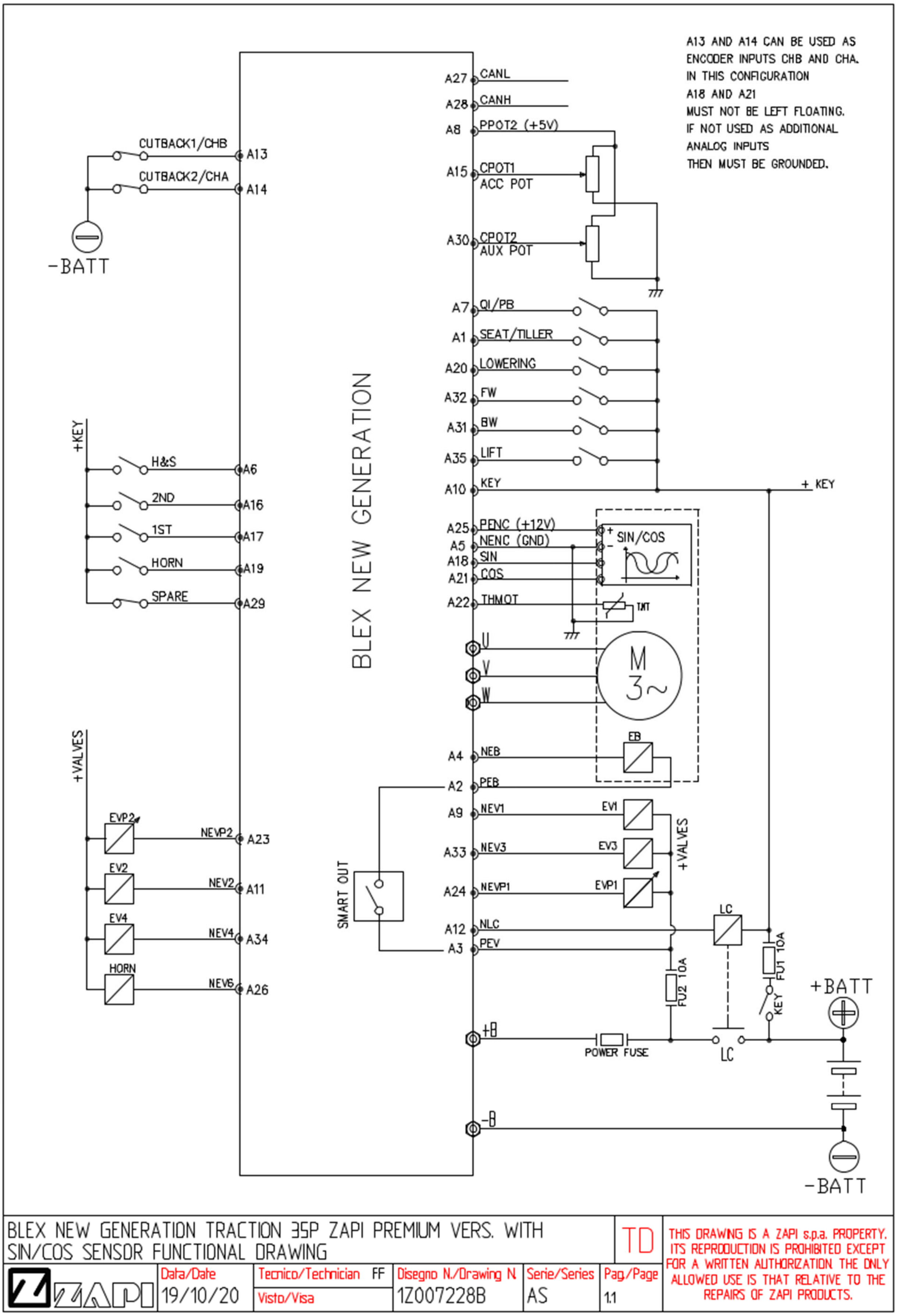
### 3.2.1 Premium version – AC traction configuration with encoder



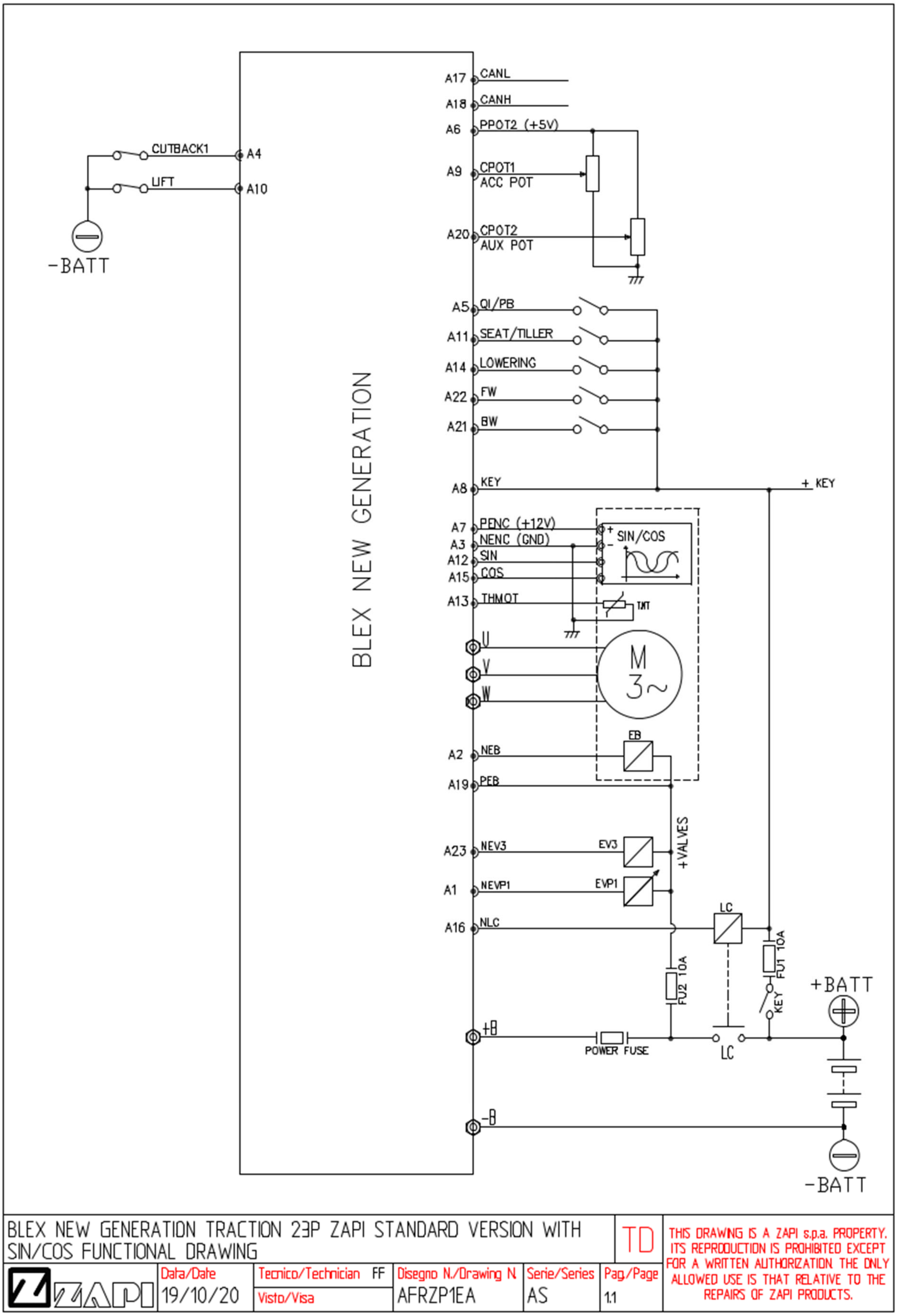
## 3.2.2 Standard version – AC traction configuration with encoder



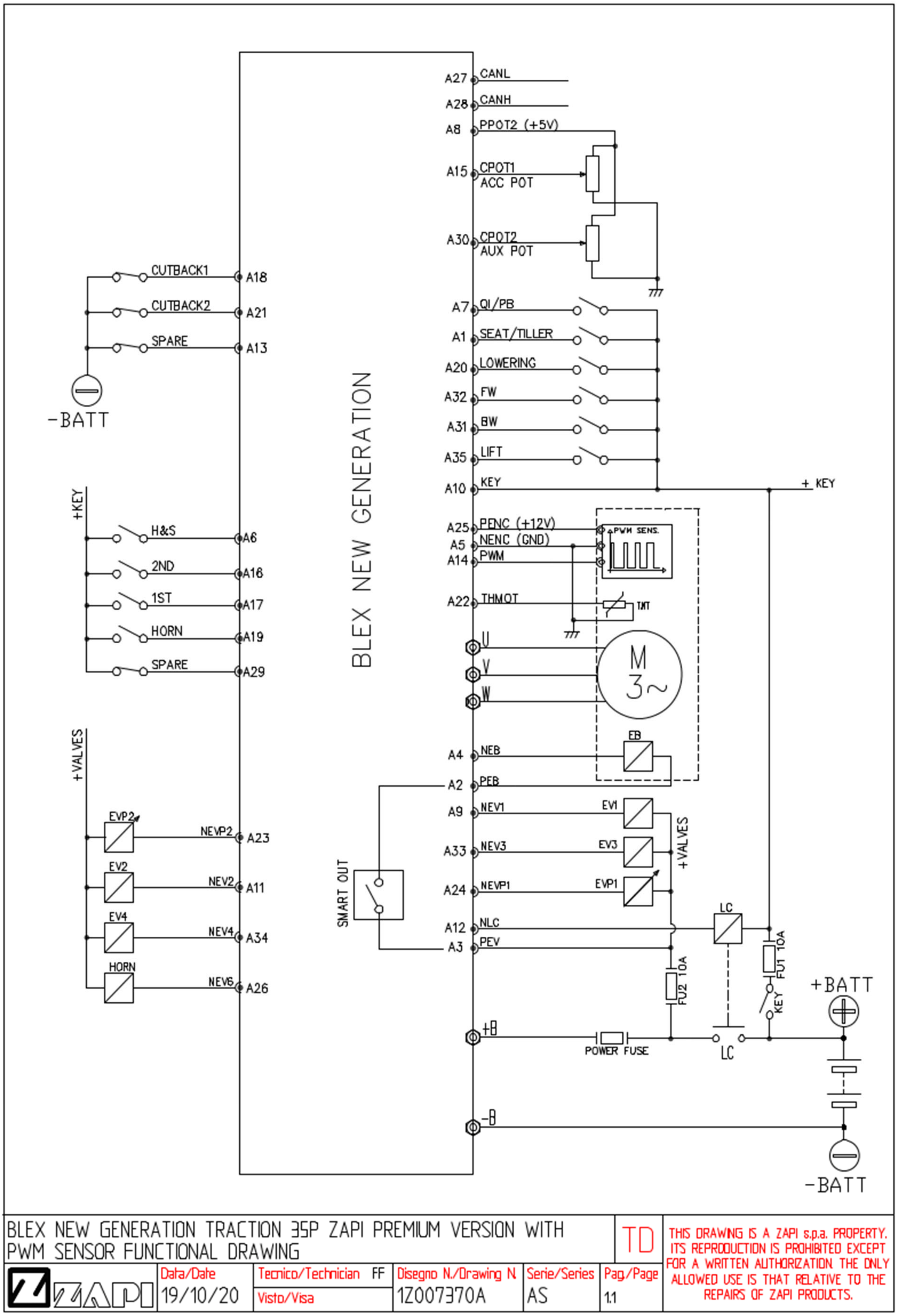
### 3.2.3 Premium version – BL traction configuration with sin/cos sensor



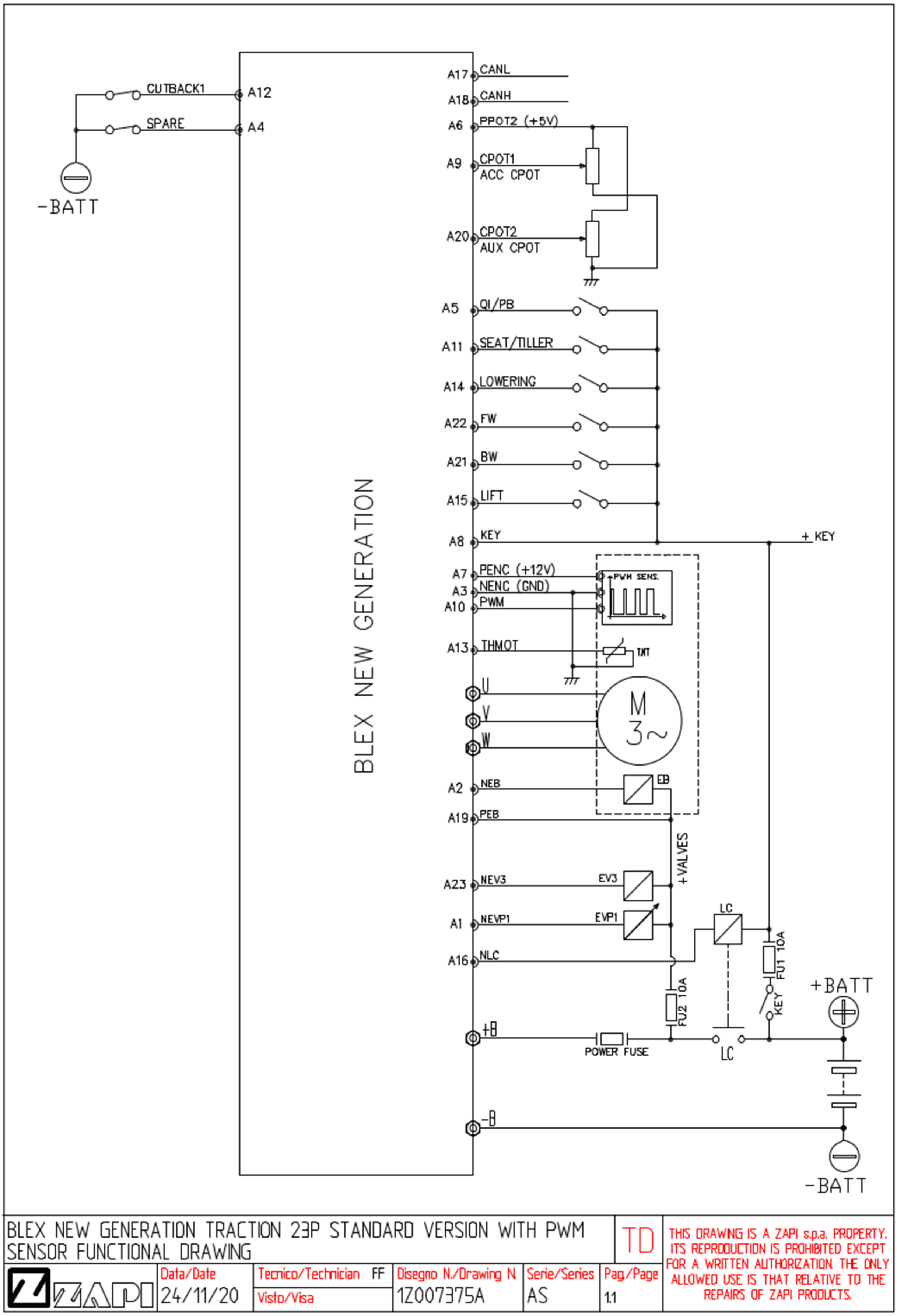
## 3.2.4 Standard version – BL traction configuration with sin/cos sensor



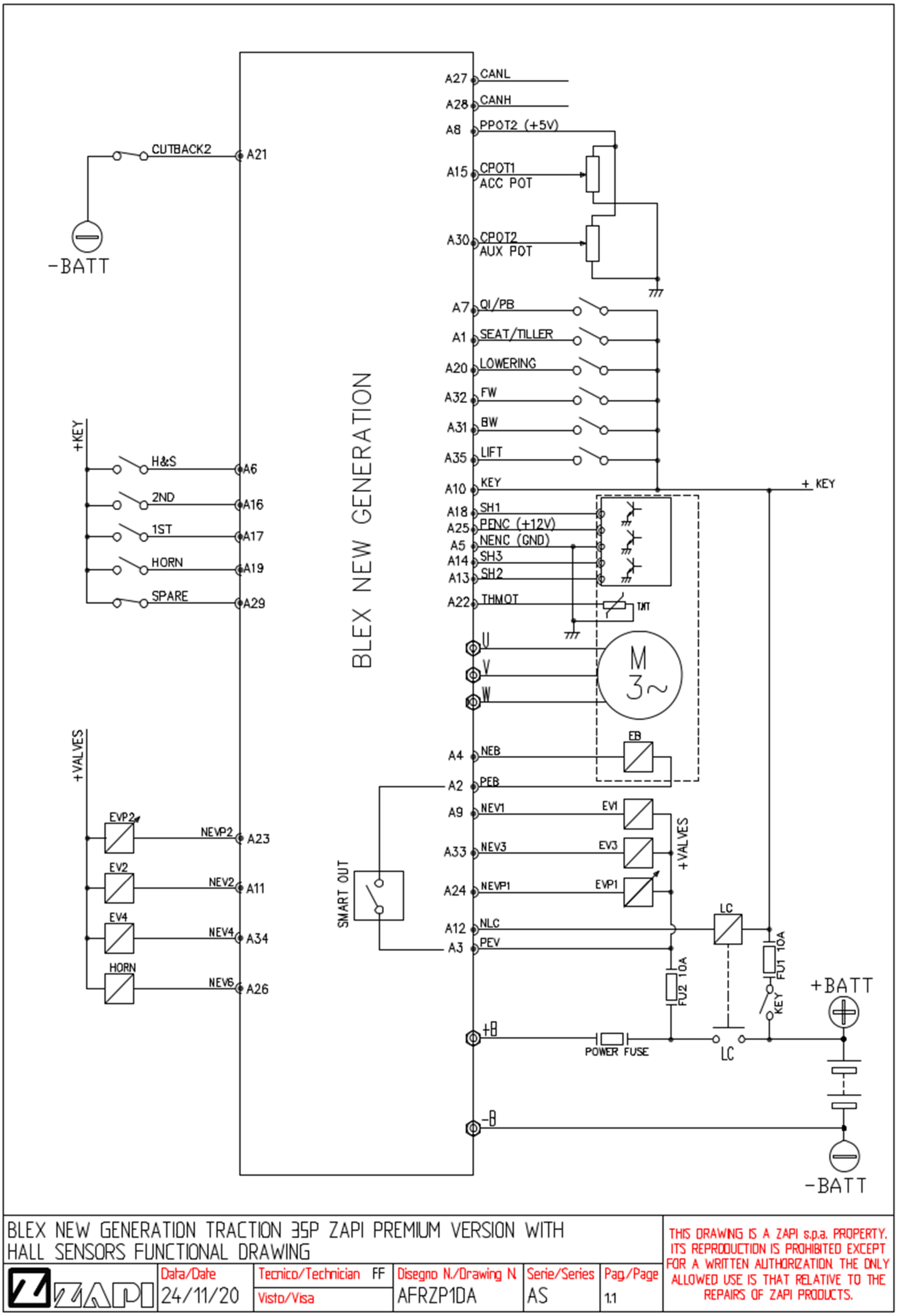
### 3.2.5 Premium version – BL traction configuration with PWM sensor



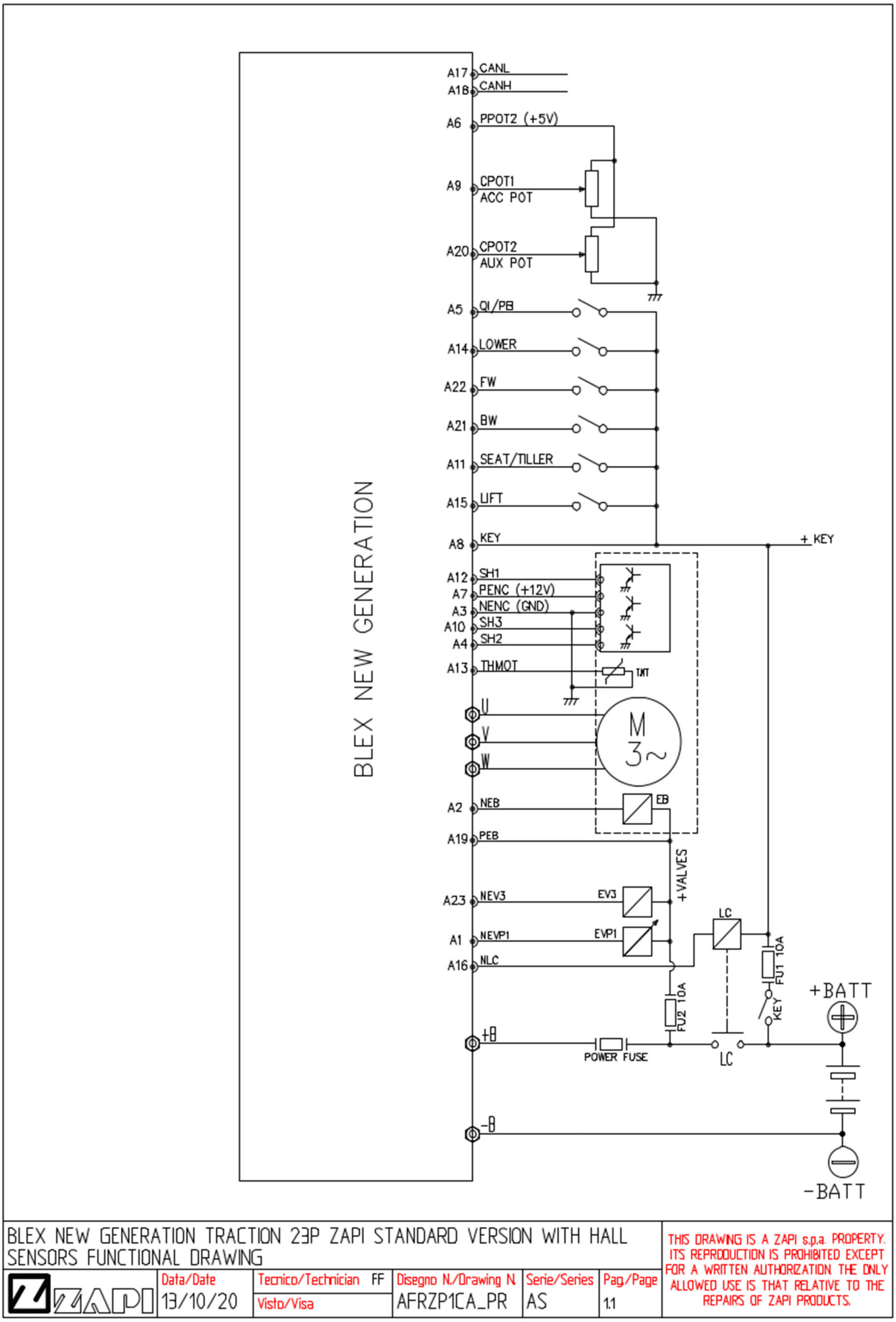
## 3.2.6 Standard version – BL traction configuration with PWM sensor



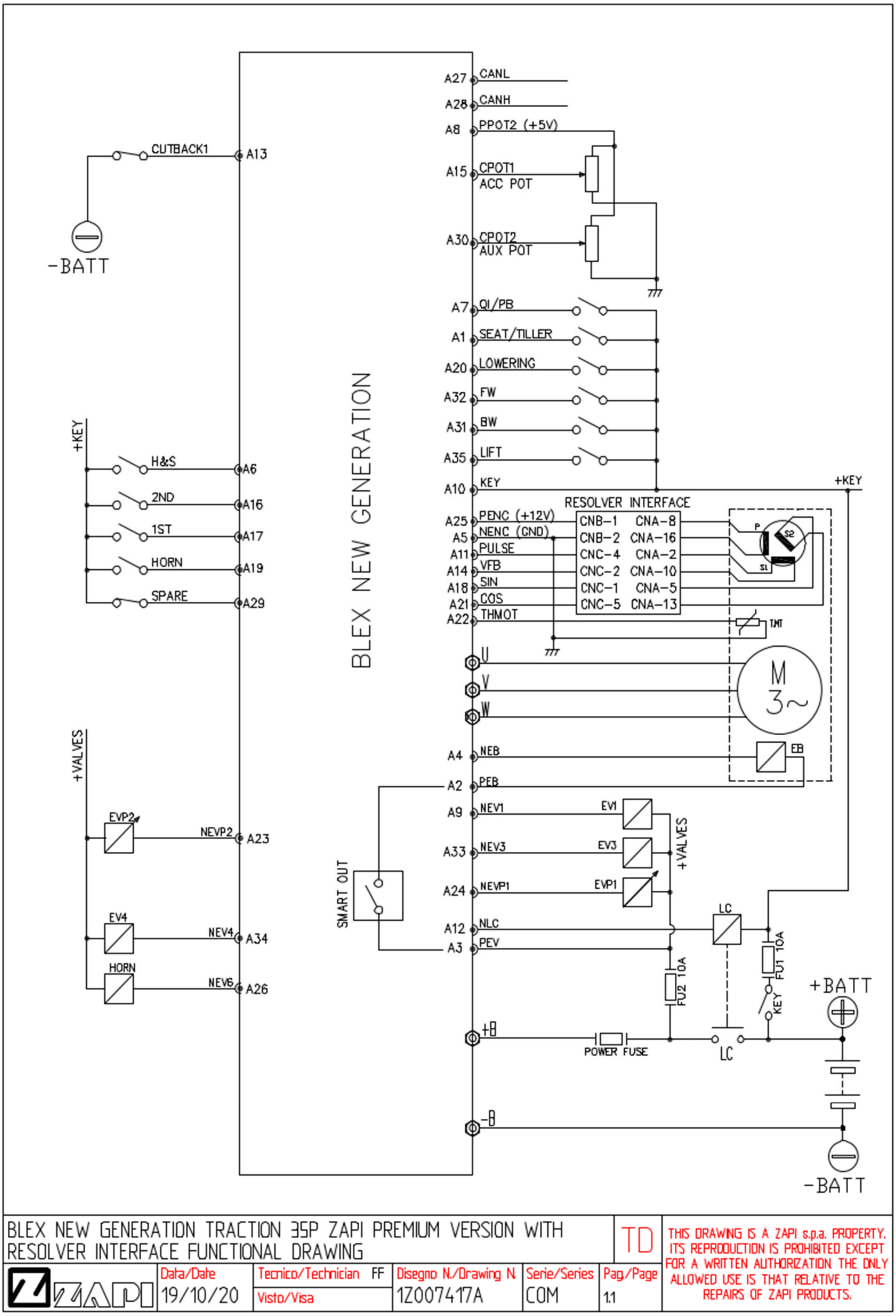
## 3.2.7 Premium version – BL traction configuration with 3-Hall sensor



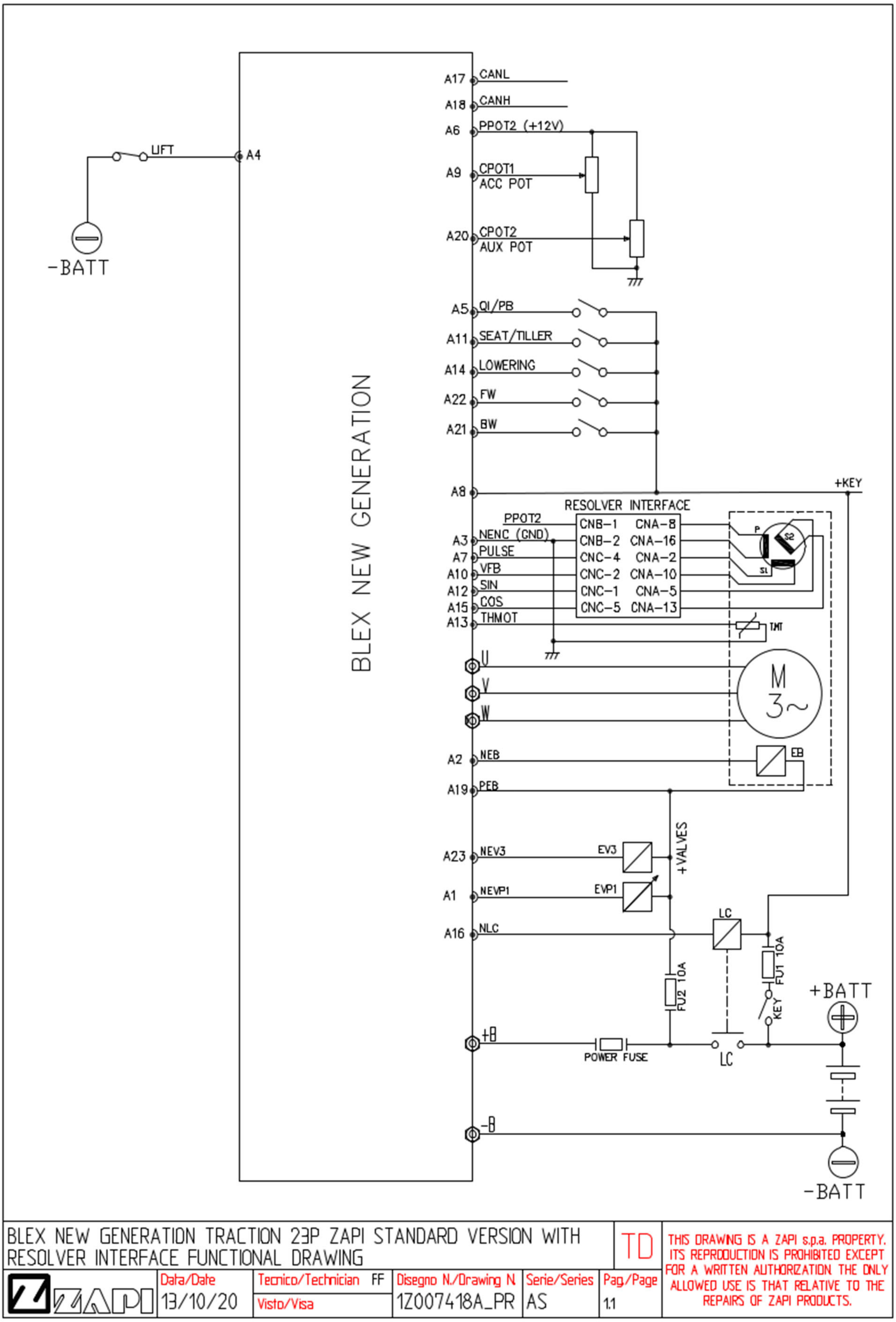
### 3.2.8 Standard version – BL traction configuration with 3-Hall sensor



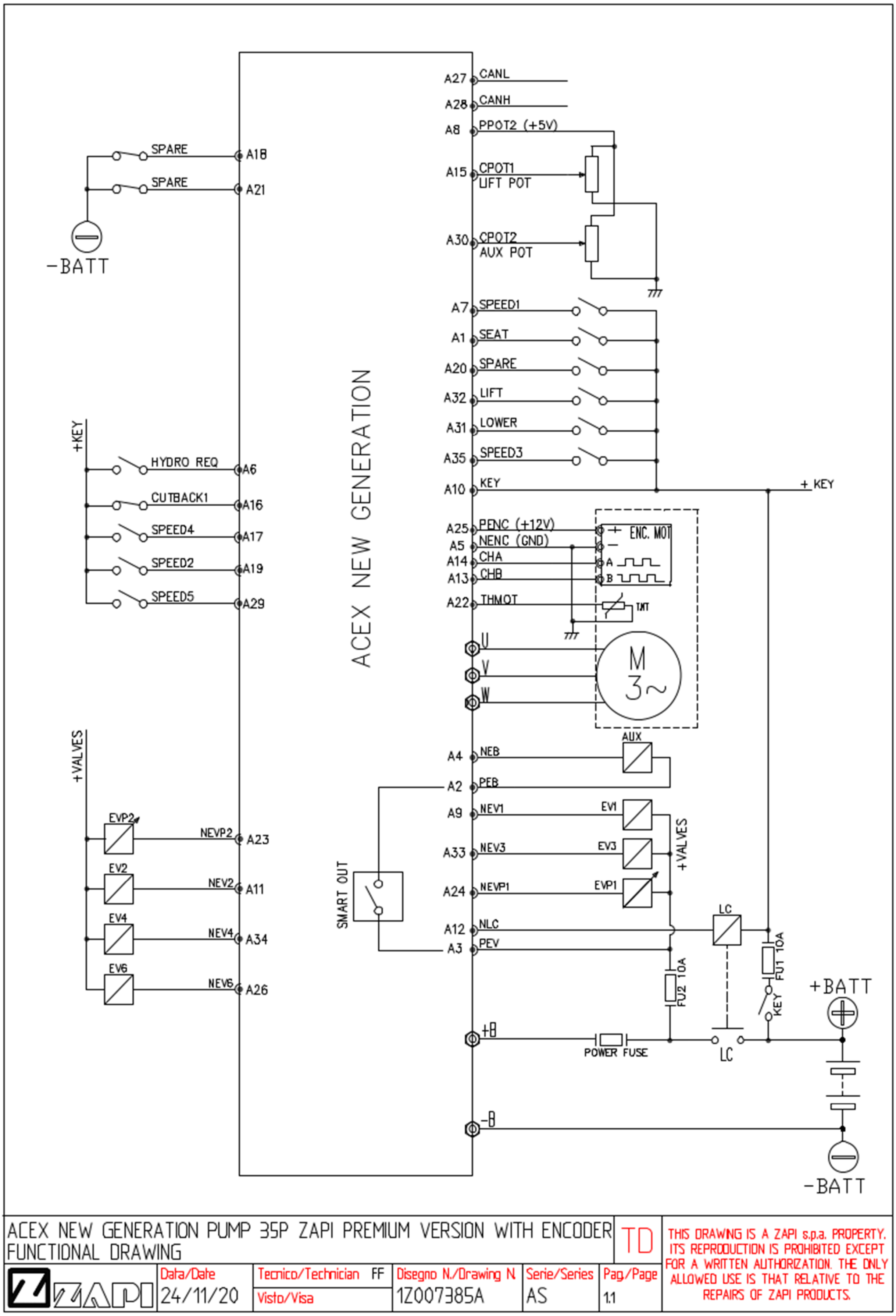
### 3.2.9 Premium version – BL traction configuration with external resolver interface



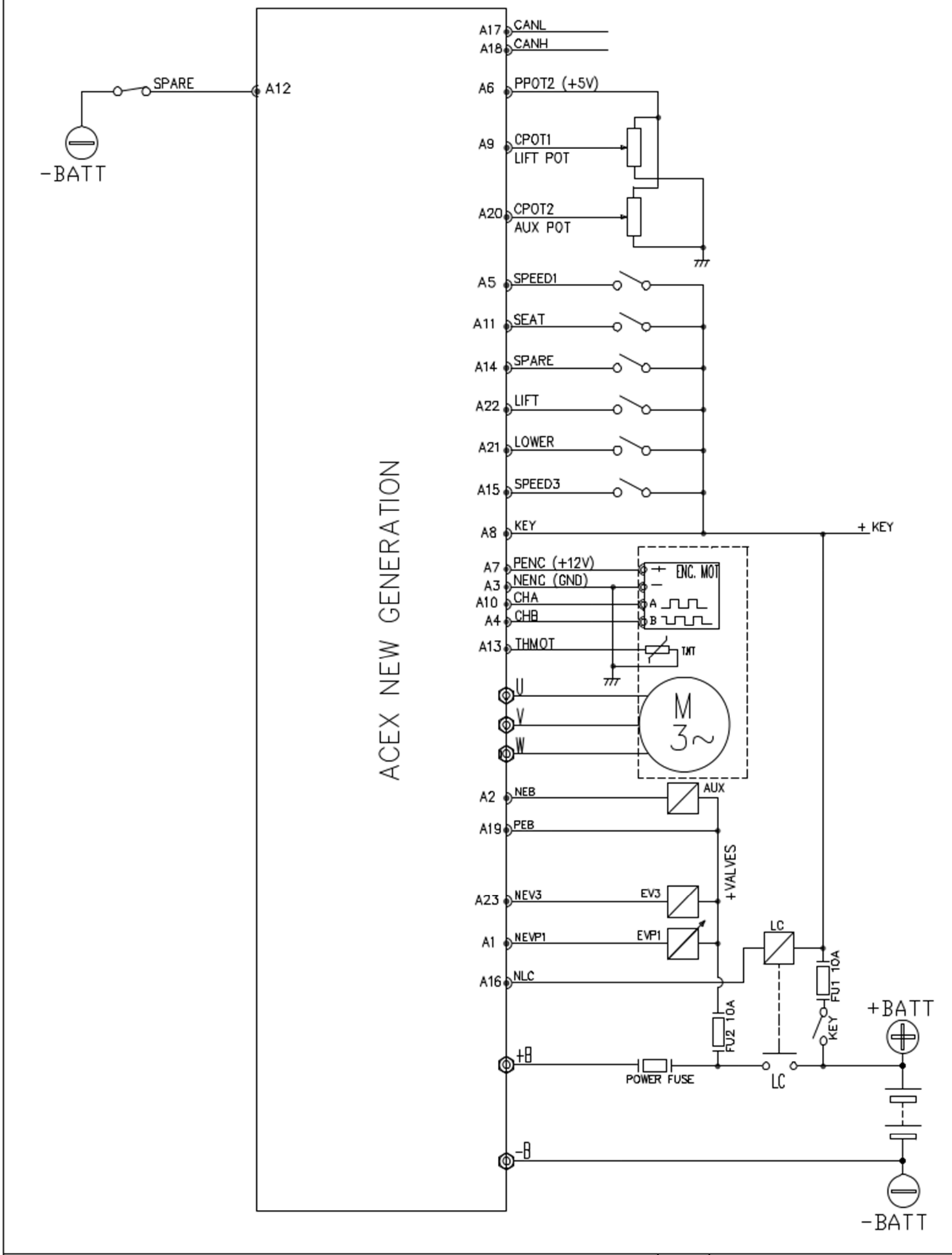
## 3.2.10 Standard version – BL traction configuration with external resolver interface



### 3.2.11 Premium version – AC pump configuration

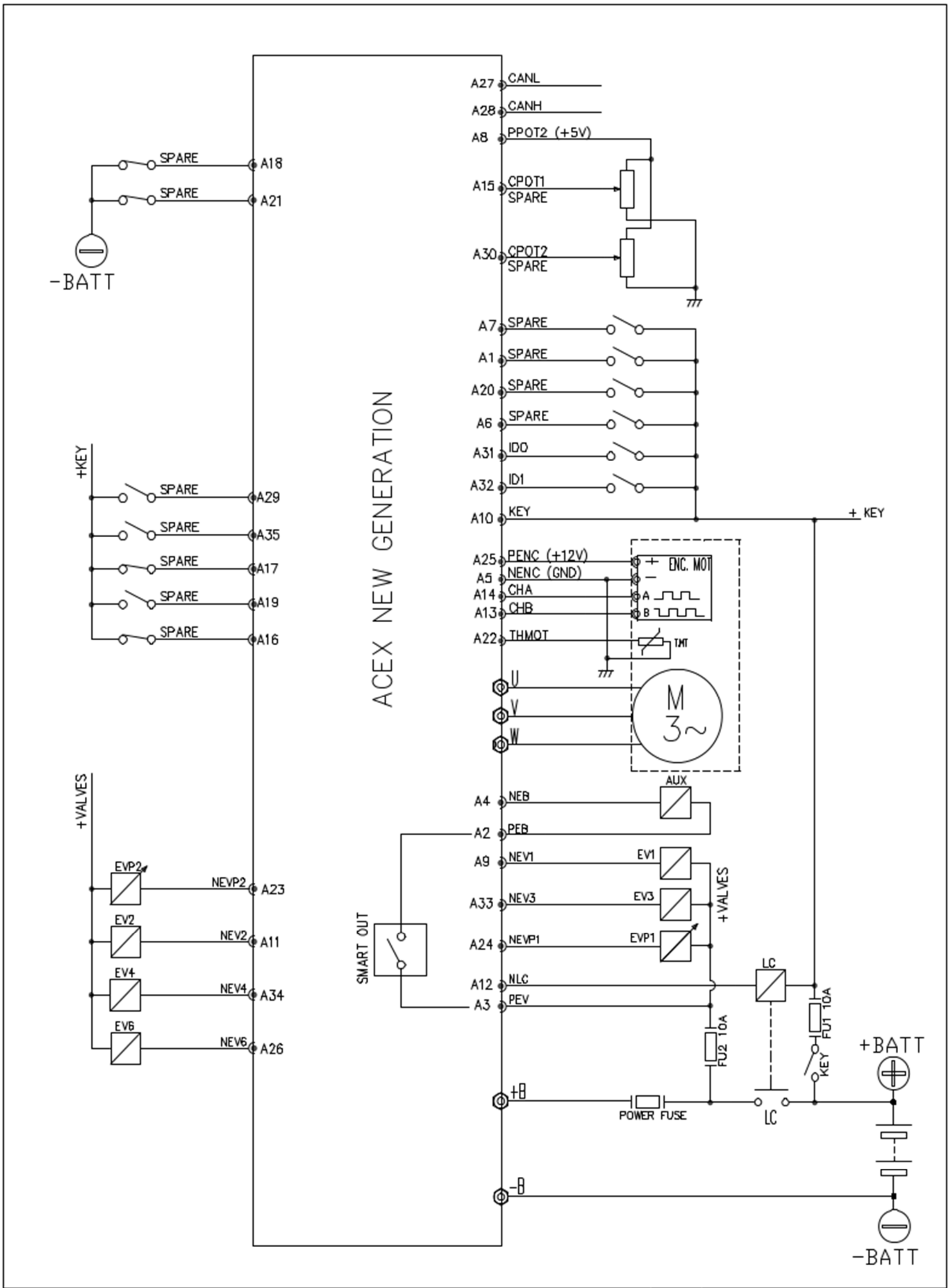


## 3.2.12 Standard version – AC pump configuration




| ACEX NEW GENERATION PUMP 23P ZAPI STANDARD VERSION WITH ENCODER 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 24/11/20 | Tecnico/Technician FF Visto/Visa | Disegno N./Drawing N. 1Z007386A | Serie/Series AS | Pag./Page 1.1 | |

### 3.2.13 Premium version – AC CAN operated




| ACEX NEW GENERATION CAN OPERATED TRACTION 3SP ZAPI PREMIUM VERSION WITH ENCODER 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. |
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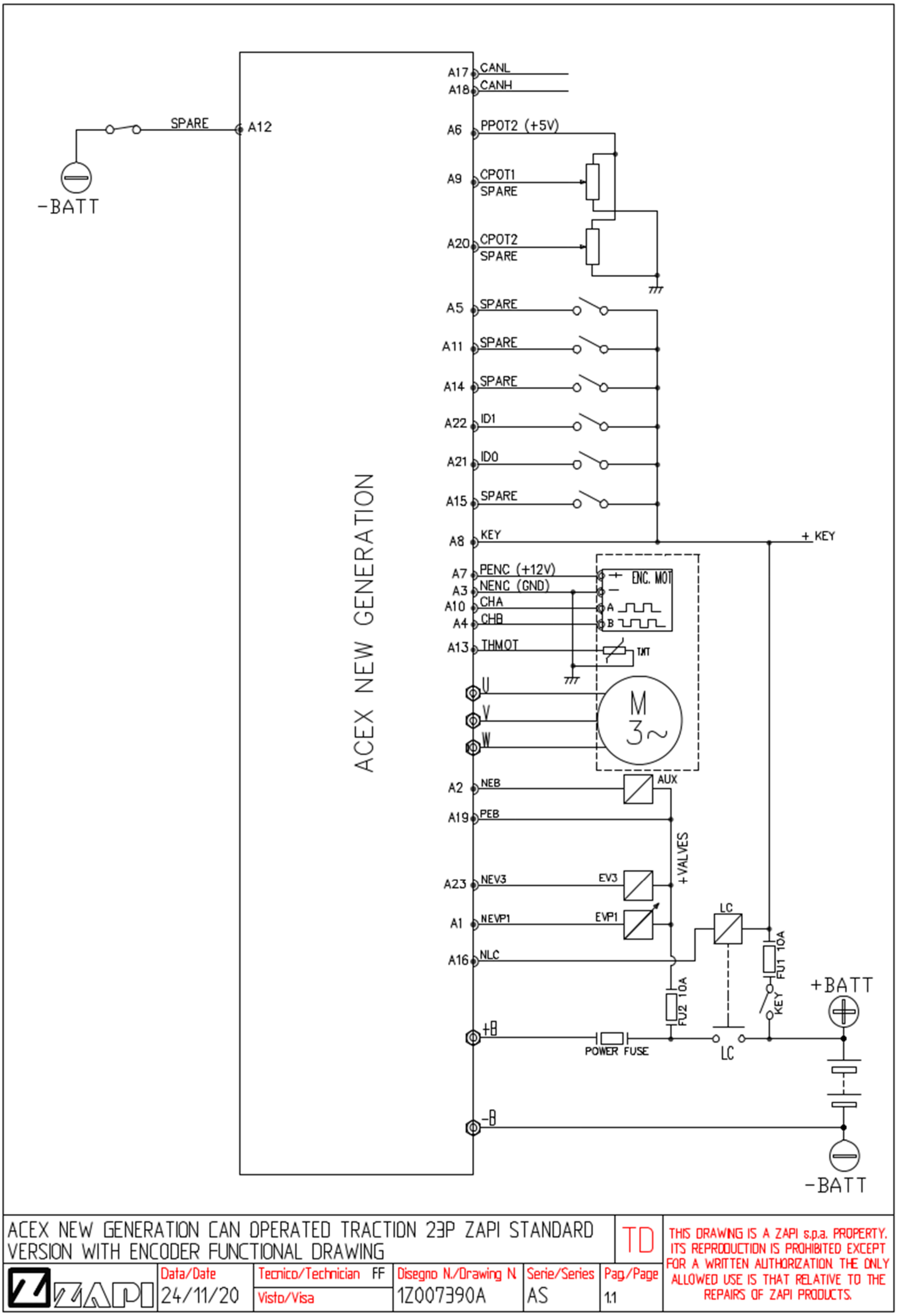
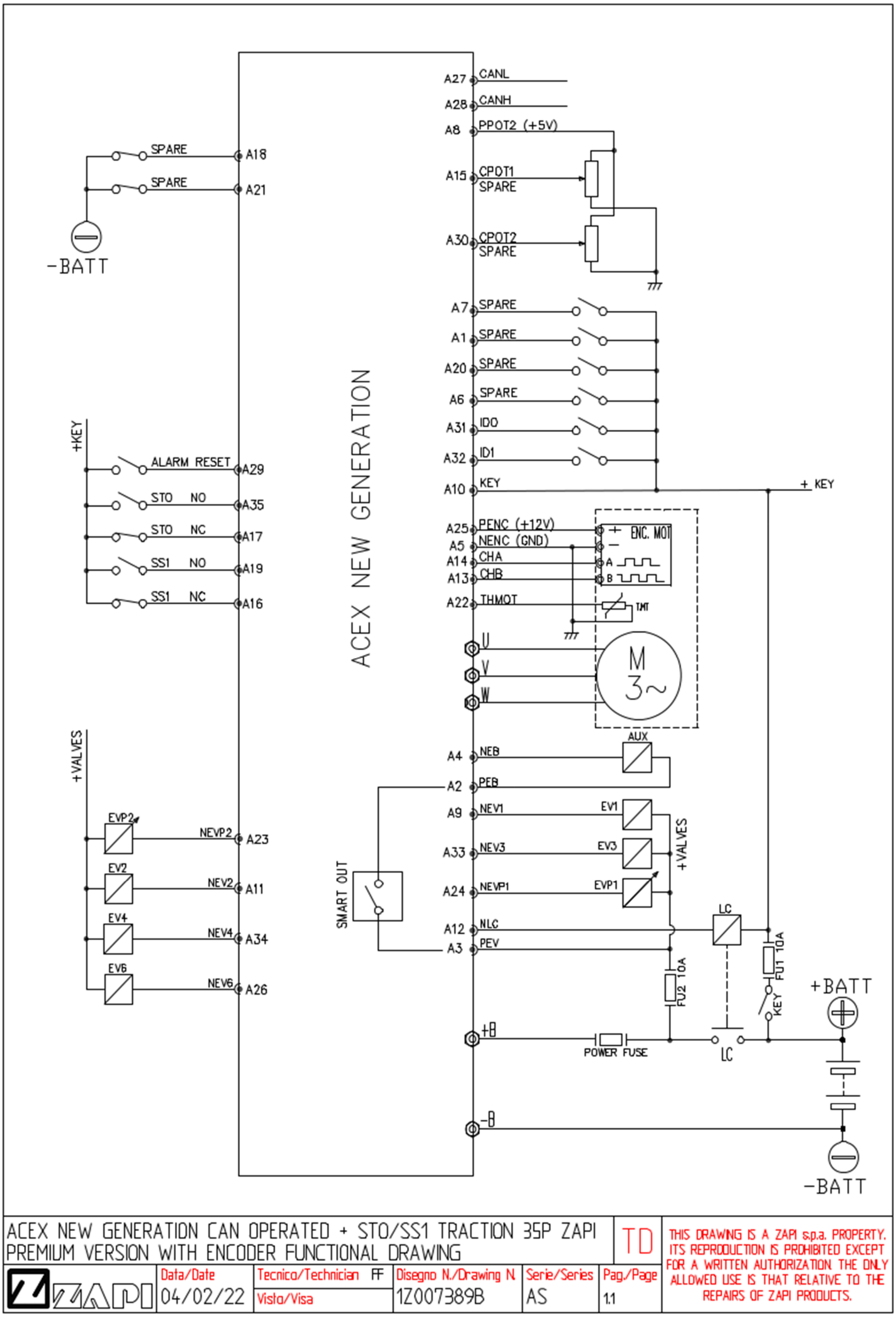
| ZAPI | Data/Date 04/02/22 | Tecnico/Technician FF Visto/Visa | Disegno N./Drawing N 1Z007980B | Serie/Series AS | Pag./Page 1.1 | |

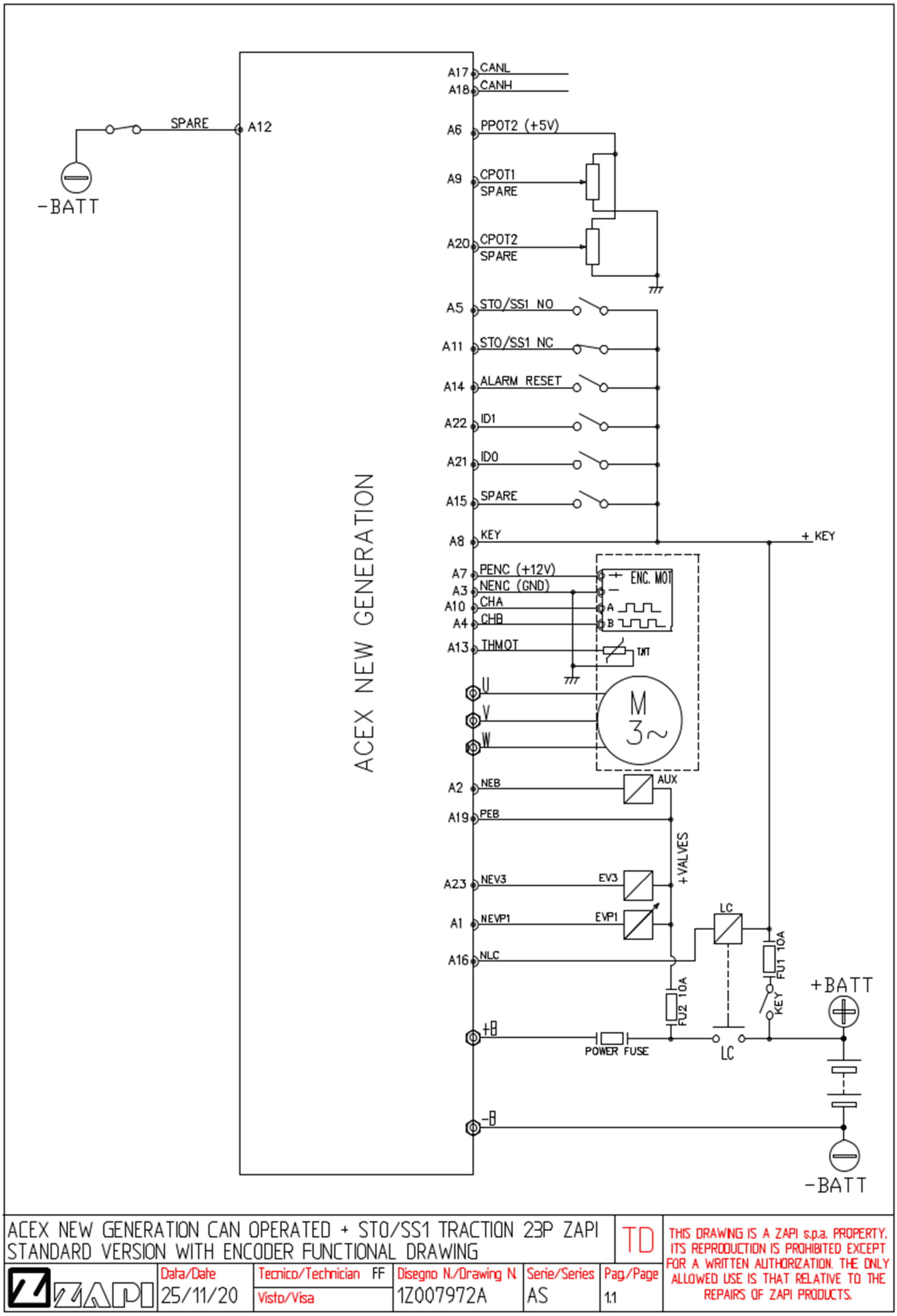
## 3.2.14 Standard version – AC CAN operated



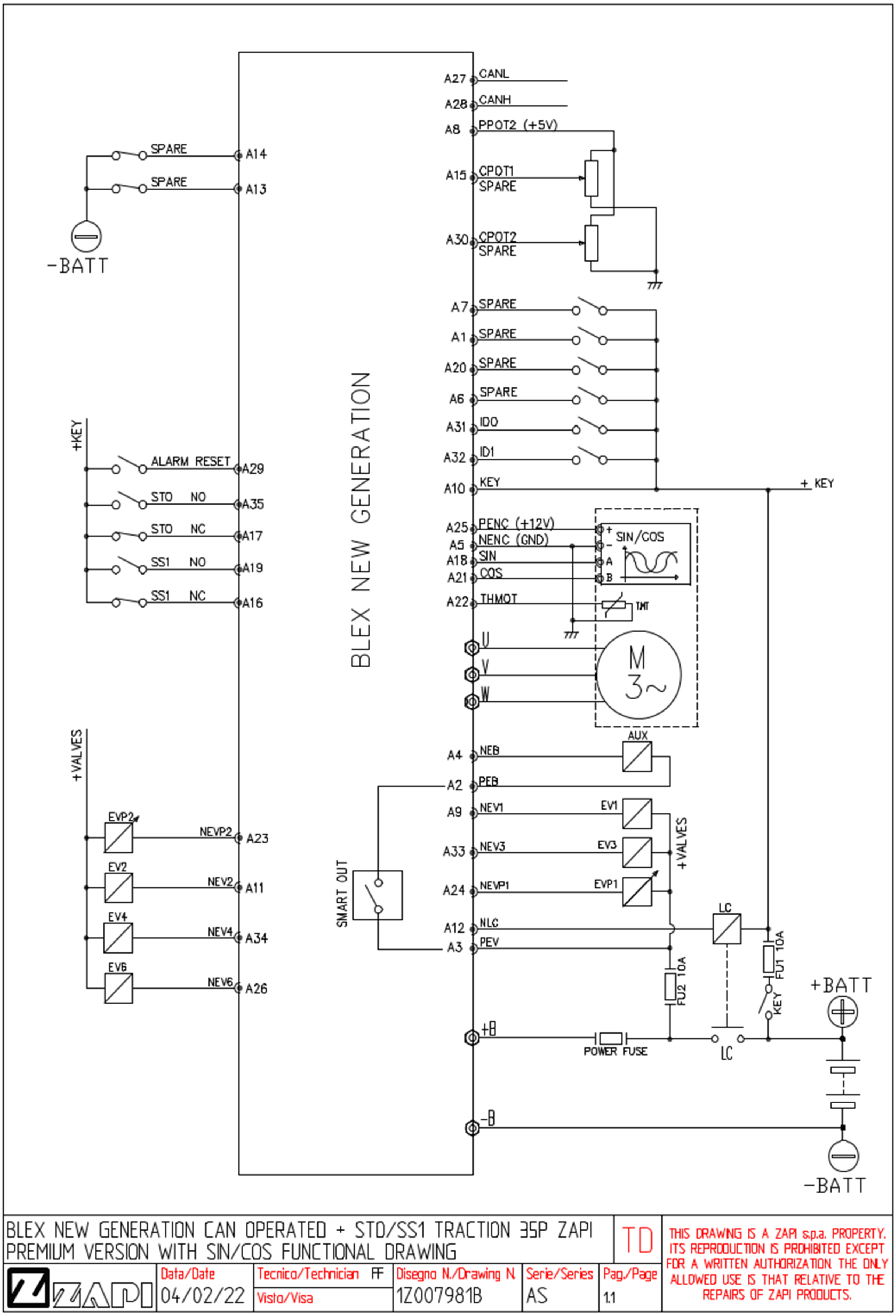
### 3.2.15 Premium version – AC CAN operated + STO and SS1 functions



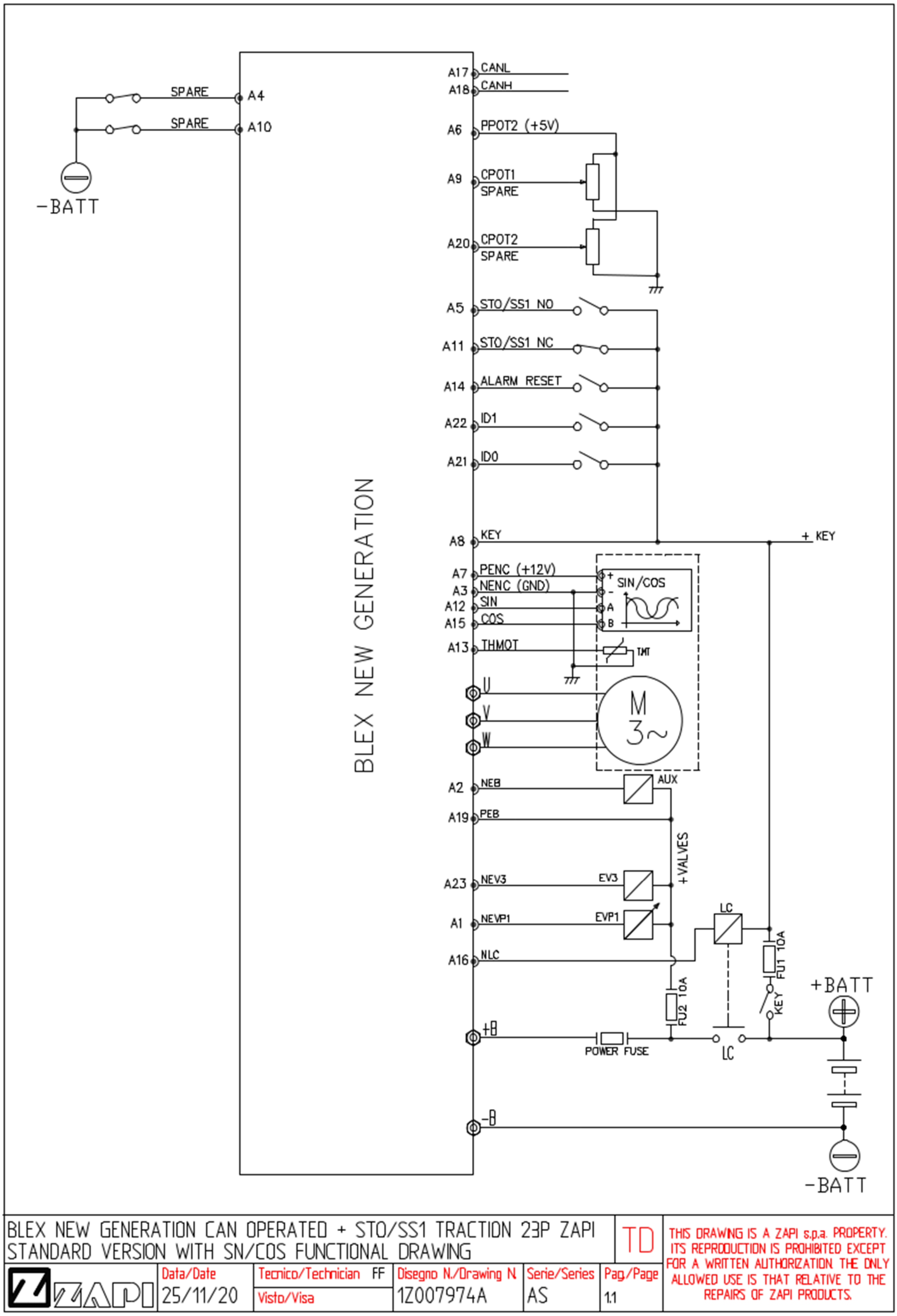
### 3.2.16 Standard version – AC CAN operated + STO or SS1 function



## 3.2.17 Premium version – BL sin/cos CAN operated + STO and SS1 functions



### 3.2.18 Standard version – BL sin/cos CAN operated + STO or SS1 function



*Any customization to the proposed configurations is possible on request: it may require a new HW and/or SW release, therefore, it must be discussed with Zapi in advance.*

# 4 I/O INTERFACE DESCRIPTION

## 4.1 Power connections

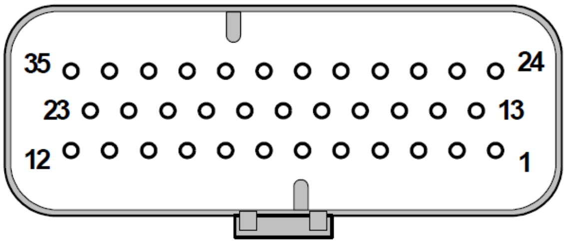
Power connections are on vertical posts where to bolt power-cables lugs. On the cover of the converter they are labeled as:

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

## 4.2 Ampseal connector

### 4.2.1 Premium Version

ACEX NEW GENERATION Foc3 Premium is equipped with a 35-poles Ampseal connector as shown in the figure below. Throughout this manual, each of the 35 pins is referred to as "A#", where "A" denotes the connector name and "#" the pin number, from 1 to 35.




*35-poles Ampseal connector of ACEX NEW GENERATION Foc3 Premium.*

*For each I/O pin has been specified the default type and functionality where available.*

*The I/O types and functionalities defined in the following inverter configurations are all available by default without any HW change, if not otherwise specified.*

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

*Any customization to the following configurations may require a new HW and/or SW release and must be discussed with Zapi in advance.*

### Premium version – ACIM traction configuration with encoder sensor

| ACEX NEW GENERATION Foc3 – Traction premium configuration with encoder | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A1 | Input | DI0-SEAT | Digital input active when connected to +B (internal pull-down). The default function is as presence input (seat or tiller). |
| A2 | Output | PEB | Positive supply for the electromechanical brake. It is supplied by pin PEV (A3) through a high-side driver activated via software in no-alarms conditions. The internal freewheeling diode of the electromechanical brake driver (A4) is connected to this pin. |
| A3 | Input | PEV | Positive supply for the high-side driver of pin PEB (A2). By default, it has to be connected after the main contactor. The internal freewheeling diodes of the electrovalves drivers are connected to this pin. |
| A4 | Output | NEB | Driving output for the electromechanical brake (driving to -B); PWM voltage controlled; 2.5 A maximum continuous current. |
| A5 | Output | NENC | Negative reference for the motor feedback sensor, the thermal sensor and the potentiometers. |
| A6 | Input | DI2-H&S | Digital input active when connected to +B (internal pull-down). The default function is as HARD & SOFT selection; if the H&S feature is enabled then closing the switch the maximum speed is reduced in agreement to a predefined software parameter. |
| A7 | Input | DI1-QI-PB | Digital input active when connected to +B (internal pull-down). The default function is quick inversion or pedal brake. Closing the switch the quick inversion function is activated. |
| A8 | Output | PPOT2 | Positive supply for the potentiometers and/or for the motor feedback sensor. The default output voltage is +5 V, 140 mA maximum. +12 V is possible on request (HW customization). |
| A9 | Output | NEV1 | Driving output for an auxiliary electrovalve (driving to -B); PWM voltage controlled; 1.5 A maximum continuous current. |
| A10 | Input | KEY | Input of the key switch signal. It is used to supply the logic section of the controller and the pre-charging circuit. |
| A11 | Output | NEV2 | Driving output for an auxiliary electrovalve (driving to -B); PWM voltage controlled; 1.5 A maximum continuous current. |
| A12 | Output | NLC | Driving output for the line – or main – contactor (driving to -B); PWM voltage controlled; 1.5 A maximum continuous current. |
| A13 | Input | CHB | Channel B of the incremental encoder. |
| A14 | Input | CHA | Channel A of the incremental encoder. |
| A15 | Input | CPOT1 | Analog input 1. The default function is as accelerator reference (wiper contact of the accelerator potentiometer). |

| ACEX NEW GENERATION Foc3 – Traction premium configuration with encoder | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A16 | Input | DI10-2ND | Digital input active when connected to +B (internal pull-down). The default function is as 2ND input; closing the switch the valve EV2 is activated. |
| A17 | Input | DI8-1ND | Digital input active when connected to +B (internal pull-down). The default function is as 1ND input; closing the switch the valve EV1 is activated. |
| A18 | Input | CUTBACK1 | Digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up). The default function is as CUTBACK SPEED 1 input; when activated, the maximum speed is reduced in agreement with the CUTBACK SPEED1 parameter, see paragraph 8.2.1. To be exploited as additional analog input a hardware customization is required. |
| A19 | Input | DI5-HORN | Digital input active when connected to +B (internal pull-down). The default function is as HORN input; closing the switch, the valve EV6 is activated. |
| A20 | Input | DI6-LOWER | Digital input active when connected to +B (internal pull-down). The default function is as lowering request. Closing the switch, the proportional valves EVP1 and EVP2 are activated according to the setpoint defined by the external potentiometer connected to A30. |
| A21 | Input | CUTBACK2 | Digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up). The default function is as CUTBACK SPEED 2 input; when activated, the maximum speed is reduced in agreement with the CUTBACK SPEED2 parameter, see paragraph 8.2.1. To be exploited as additional analog input a hardware customization is required. |
| A22 | Input | THMOT | Analog input. Current-mode temperature sensing of the motor. 2 mA operation. Internally clamped to 5 V. |
| A23 | Output | NEVP2 | Driving output for a proportional electrovalve (driving to -B); PWM current controlled; 1.7 A maximum continuous current. The default PWM frequency is 1 kHz; different frequencies may be available on request. A dithering feature is also available, see paragraph 4.3.9. |
| A24 | Output | NEVP1 | Driving output for a proportional electrovalve (driving to -B); PWM current controlled; 1.7 A maximum continuous current. The default PWM frequency is 1 kHz; different frequencies may be available on request. A dithering feature is also available, see paragraph 4.3.9. |
| A25 | Output | PENC | Positive supply for the motor feedback sensor and/or for the potentiometers. The default output voltage is +12 V, 200 mA maximum. +5 V is possible on request (HW customization). |
| A26 | Output | NEV6 | Driving output for an auxiliary electrovalve (driving to -B); PWM voltage controlled; 1.5 A maximum continuous current. |

| ACEX NEW GENERATION Foc3 – Traction premium configuration with encoder | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A27 | In/Out | CANL | Low-level CAN bus line. |
| A28 | In/Out | CANH | High-level CAN bus line. |
| A29 | Input | DI9-SPARE | Digital input connected to +B (internal pull-down).<br>The input is activated when the external switch is opened.<br>No default function assigned. |
| A30 | Input | CPOT2 | Analog input 2. The default function is as breaking reference or as reference for the aperture of the proportional electrovalves EVP1 and EVP2, depending on the function being active.<br>If PEDAL BRK ANALOG = ON this input is used as analog brake input.<br>Otherwise, if AUX POT. TYPE is different from 12, this input is used as reference for the lowering proportional valves EVP1 and EVP2. |
| A31 | Input | DI4-BW | Digital input active when connected to +B (internal pull-down).<br>The default function is as backward request; closing this input the truck moves backward. Moreover, if enabled, closing this switch the EV4 is activated. |
| A32 | Input | DI3-FW | Digital input active when connected to +B (internal pull-down).<br>The default function is as forward request; closing this input the truck moves forward. Moreover, if EV5 is enabled, closing this switch the EV5 is activated. |
| A33 | Output | NEV3 | Driving output for an auxiliary electrovalve (driving to -B); PWM voltage controlled; 1.5 A maximum continuous current. |
| A34 | Output | NEV4 | Driving output for an auxiliary electrovalve (driving to -B); PWM voltage controlled; 1.5 A maximum continuous current. |
| A35 | Input | DI7-LIFT | Digital input active when connected to +B (internal pull-down). The default function is as lift function; closing the switch the valve EV3 is activated. |

### Premium version – ACIM pump configuration with encoder sensor

When the inverter is configured as ACEX NEW GENERATION for controlling an AC pump motor endowed with an encoder sensor, see paragraph 3.2.11, the pinout differs from that of the AC traction configuration with encoder only for the pins listed in the following table. The other ones are unchanged both in name and in function.

| ACEX NEW GENERATION Foc3 – Pump premium configuration with encoder | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A2 | Output | PEB | Positive supply for the auxiliary electrovalve driven by pin (A4). It is supplied by pin PEV (A3) through a high-side driver activated via software in no-alarms conditions and if the auxiliary output is enabled. The internal freewheeling diode of the auxiliary electrovalve driver (A4) is connected to this pin. |

| ACEX NEW GENERATION Foc3 – Pump premium configuration with encoder | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A4 | Output | NEB | Driving output for an auxiliary electrovalve (driving to -B); PWM voltage controlled; 2.5 A maximum continuous current. |
| A6 | Input | DI2-HYDRO REQ | Digital input active when connected to +B (internal pull-down).<br>The default function is as HYDRO request; closing the switch, the AC pump motor is activated at the speed defined by the parameter HYD PUMP SPEED. |
| A7 | Input | DI1-SPEED 1 | Digital input active when connected to +B (internal pull-down).<br>The default function is as 1ST pump motor speed; closing the switch the $1^{ST}$ pump motor speed is selected, in agreement with the $1^{ST}$ PUMP SPEED parameter. If enabled, closing the switch the valve EV1 is activated. |
| A15 | Input | CPOT1 | Analog input 1. The default function is as a reference for the lift pump motor (wiper contact of the lift potentiometer). |
| A16 | Input | DI10-CUTBACK1 | Digital input connected to +B (internal pull-down).<br>The input is activated when the external switch is opened.<br>The default function is as LIFT CUTBACK input; when activated, the AC pump motor maximum speed is reduced in agreement with the CUTBACK SPEED1 parameter, see paragraph 8.2.1. |
| A17 | Input | DI8-SPEED4 | Digital input active when connected to +B (internal pull-down).<br>The default function is as $4^{ST}$ pump motor speed; closing the switch the $4^{ST}$ pump motor speed is selected, in agreement with the 4TH PUMP SPEED parameter. |
| A18 | Input | SPARE | Spare digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up).<br>No default function assigned. |
| A19 | Input | DI5-SPEED2 | Digital input active when connected to +B (internal pull-down).<br>The default function is as $2^{ST}$ pump motor speed; closing the switch the $2^{ST}$ pump motor speed is selected, in agreement with the 1ST PUMP SPEED parameter. Closing the switch the valve EV2 is activated. |
| A20 | Input | DI6-SPARE | Spare digital input active when connected to +B (internal pull-down). No default function assigned. |
| A21 | Input | SPARE | Spare digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up).<br>No default function assigned. |
| A23 | Output | NEVP2 | Spare driving output for a proportional electrovalve (driving to -B); PWM current controlled; 1.7 A maximum continuous current.<br>No default function assigned. |
| A24 | Output | NEVP1 | Driving output for a proportional electrovalve (driving to -B); PWM current controlled; 1.7 A maximum continuous current. The default PWM frequency is 1 kHz; different frequencies may be available on request. A dithering feature is also available, see paragraph 4.3.9. Digital control mode only. The analog control mode is not available in this configuration. |

| ACEX NEW GENERATION Foc3 – Pump premium configuration with encoder | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A26 | Output | NEV6 | Spare driving output for an auxiliary electrovalve (driving to -B); PWM voltage controlled; 1.5 A maximum continuous current. |
| A29 | Input | DI9-SPEED5 | Digital input active when connected to +B (internal pull-down). The default function is as 5ST pump motor speed; closing the switch the 5ST pump motor speed is selected, in agreement with the 5TH PUMP SPEED parameter. |
| A30 | Input | CPOT2 | Spare analog input 2. No default function assigned. |
| A31 | Input | DI4-LOWER | Digital input active when connected to +B (internal pull-down). The default function is as lowering request; closing the switch the NEVP1 output is activated according to the MAX EVP parameter. |
| A32 | Input | DI3-LIFT | Digital input active when connected to +B (internal pull-down). The default function is as lift request; closing this input the pump motor is activated. The motor speed is controlled with the lift potentiometer; input A15. |
| A34 | Output | NEV4 | Spare driving output for an auxiliary electrovalve (driving to -B); PWM voltage controlled; 1.5 A maximum continuous current. |
| A35 | Input | DI7-SPEED3 | Digital input active when connected to +B (internal pull-down). The default function is as 3ST pump motor speed; closing the switch the 3ST pump motor speed is selected, in agreement with the 3RD PUMP SPEED parameter. Closing the switch the valve EV3 is activated. |

### Premium version – PMSM traction configuration with sin/cos sensor

When the inverter is configured as BLEX NEW GENERATION for controlling a PM synchronous traction motor endowed with a sin/cos sensor, see paragraph 3.2.3, the pinout differs from that of the AC traction configuration with encoder sensor only for the pins listed in the following table. The other ones are unchanged both in name and in function.

| BLEX NEW GENERATION – Traction premium configuration with sin/cos sensor | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A13 | Input | CUTBACK1/CHB | Digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up). The default function is as CUTBACK SPEED 1 input; when activated, the maximum speed is reduced in agreement with the CUTBACK SPEED1 parameter, see paragraph 8.2.1.<br>If FEEDBACK SENSOR (see paragraph 8.2.7) is set to 0, this pin is used as channel B of the incremental encoder. |
| A14 | Input | CUTBACK2/CHA | Digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up). The default function is as CUTBACK SPEED 2 input; when activated, the maximum |

| BLEX NEW GENERATION – Traction premium configuration with sin/cos sensor | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| | | | speed is reduced in agreement with the CUTBACK SPEED2 parameter, see paragraph 8.2.1.<br>If FEEDBACK SENSOR (see paragraph 8.2.7) is set to 0, this pin is used as channel A of the incremental encoder. |
| A18 | Input | SIN | Sine signal of the sin/cos sensor.<br>If FEEDBACK SENSOR (see paragraph 8.2.7) is set to 0, this pin may be used as additional analog input with a voltage range 0 V ÷ 5 V. If not used must be connected to pin NENC (A5). |
| A21 | Input | COS | Cosine signal of the sin/cos sensor.<br>If FEEDBACK SENSOR (see paragraph 8.2.7) is set to 0, this pin may be used as additional analog input with a voltage range 0 V ÷ 5 V. If not used must be connected to pin NENC (A5). |

### Premium version – PMSM traction configuration with PWM sensor

When the inverter is configured as BLEX NEW GENERATION for controlling a PM synchronous traction motor endowed with a PWM sensor, see paragraph 3.2.5, the pinout differs from that of the AC traction configuration with encoder sensor only for the pins listed in the following table. The other ones are unchanged both in name and in function.

| BLEX NEW GENERATION – Traction premium configuration with PWM sensor | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A13 | Input | DI13-SPARE | Spare digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up). No default function assigned. |
| A14 | Input | PWM | PWM signal of the PWM sensor. |
| A26 | Output | NEV6 | Driving output for an auxiliary electrovalve (driving to -B); ON/OFF control mode only; 1.5 A maximum continuous current. |

### Premium version – PMSM traction configuration with 3-Hall sensors

When the inverter is configured as BLEX NEW GENERATION for controlling a PM synchronous traction motor endowed with 3-Hall feedback sensors, see paragraph 3.2.7, the pinout differs from that of the AC traction configuration with encoder sensor only for the pins listed in the following table. The other ones are unchanged both in name and in function.

| BLEX NEW GENERATION – Traction premium configuration with 3-Hall sensors | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A13 | Input | SH2 | Input signal from the Hall sensor 2. |

| BLEX NEW GENERATION – Traction premium configuration with 3-Hall sensors | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A14 | Input | SH3 | Input signal from the Hall sensor 3. |
| A18 | Input | SH1 | Input signal from the Hall sensor 1. |

### Premium version – PMSM traction configuration with external resolver sensor interface

When the inverter is configured as BLEX NEW GENERATION for controlling a PM synchronous traction motor endowed with the external Zapi resolver interface, see paragraph 3.2.9, the pinout differs from that of the AC traction configuration with encoder sensor only for the pins listed in the following table. The other ones are unchanged both in name and in function.

| BLEX NEW GENERATION<br>Traction premium configuration with external resolver sensor interface | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A11 | Output | Pulse out | Digital output in the 0 - 5 V range. Driving output for the resolver interface digital input command pulse. |
| A13 | Input | CUTBAC K1 | Digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up). The default function is as CUTBACK SPEED 1 input; when activated, the maximum speed is reduced in agreement with the CUTBACK SPEED1 parameter, see paragraph 8.2.1. |
| A14 | Input | Vfb | Analog input. The default function is as resolver excitation pulse voltage feedback, in the 0 - 5V range with 0V offset. |
| A18 | Input | SIN | Sine input signal from the external resolver interface. |
| A21 | Input | COS | Cosine input signal from the external resolver interface. |
| A33 | Output | NEV3 | Driving output for an auxiliary electrovalve (driving to -B); ON/OFF control mode only; 1.5 A maximum continuous current. |

### Premium version – ACIM traction CAN operated configuration with encoder sensor

When the inverter is configured as premium ACEX NEW GENERATION for controlling an AC traction motor endowed with an encoder sensor, in a CAN operated configuration, see paragraph 3.2.13, the pinout differs from that of the premium AC traction configuration with encoder only for the pins listed in the following table. The other ones are unchanged both in name and in function.

| ACEX NEW GENERATION Foc3<br>Traction CAN operated premium configuration with encoder | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A1 | Input | DI0 - SPARE | Spare digital input active when connected to +B (internal pull-down). No default function assigned. |
| A2 | Output | PEB | Positive supply for the auxiliary electrovalve driven by pin (A4). It is supplied by pin PEV (A3) through a high-side driver activated via software in no-alarms conditions and if the auxiliary output is enabled. The internal freewheeling diode of the auxiliary electrovalve driver (A4) is connected to this pin. |
| A4 | Output | NEB | Driving output for an auxiliary electrovalve (driving to -B); PWM voltage controlled; 2.5 A maximum continuous current. |
| A6 | Input | DI2-SPARE | Spare digital input active when connected to +B (internal pull-down). No default function assigned. |
| A7 | Input | DI1-SPARE | Spare digital input active when connected to +B (internal pull-down). No default function assigned. |
| A15 | Input | CPOT1 SPARE | Spare analog input 1. No default function assigned. |
| A16 | Input | DI10-SPARE | Spare digital input normally closed to +B (internal pull-down). The input is activated when the external switch is opened.<br>No default function assigned. |
| A17 | Input | DI8-SPARE | Spare digital input normally closed to +B (internal pull-down). The input is activated when the external switch is opened.<br>No default function assigned. |
| A18 | Input | DI11-SPARE | Spare digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up).<br>No default function assigned. |
| A19 | Input | DI5-SPARE | Spare digital input active when connected to +B (internal pull-down). No default function assigned. |
| A20 | Input | DI6-SPARE | Spare digital input active when connected to +B (internal pull-down). No default function assigned. |
| A21 | Input | DI12-SPARE | Spare digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up).<br>No default function assigned. |
| A29 | Input | DI9-SPARE | Spare digital input active when connected to +B (internal pull-down). No default function assigned. |
| A30 | Input | CPOT2-SPARE | Spare analog input 2. No default function assigned. |
| A31 | Input | NODE ID0 | Digital input active when connected to +B (internal pull-down).<br>The default function is as NODE ID0 selection. |
| A32 | Input | NODE ID1 | Digital input active when connected to +B (internal pull-down).<br>The default function is as NODE ID1 selection. |

| ACEX NEW GENERATION Foc3<br>Traction CAN operated premium configuration with encoder | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A35 | Input | DI7-SPARE | Spare digital input active when connected to +B (internal pull-down). No default function assigned. |

The default node identification number of the controller over the CAN bus is determined by the two NODE ID inputs as specified in the table below:

| NODE ID1 | NODE ID0 | CONTROLLER NODE ID |
|---|---|---|
| 0 | 0 | 8 |
| 0 | 1 | 10 |
| 1 | 0 | 12 |
| 1 | 1 | 14 |

By default, up to 4 different Zapi inverters can be identified over the CAN network.

### Premium version – ACIM traction CAN operated configuration with encoder sensor + STO and SS1 functions

When the inverter is configured as premium ACEX NEW GENERATION for controlling an AC traction motor endowed with an encoder sensor, in a CAN operated configuration with safe stop 1 (SS1) and safe torque off (STO) functions, see paragraph 3.2.15, the pinout differs from that of the premium AC CAN operated traction configuration with encoder only for the pins listed in the following table. The other ones are unchanged both in name and in function.

| ACEX NEW GENERATION Foc3<br>Traction CAN operated premium configuration with encoder + STO and SS1 functions | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A16 | Input | DI10-SS1 NC | Safe stop digital input normally closed to +B (internal pull-down). The input is activated when the external switch is opened.<br>If the Safe Stop 1 function is enabled, opening the switch the inverter implements a safe stop of category 1 in accordance with IEC 60204-1. |
| A17 | Input | DI8-STO NC | Safe torque off digital input normally closed to +B (internal pull-down). The input is activated when the external switch is opened. If the Safe Torque Off function is enabled, opening the switch the inverter implements a safe stop of category 0 in accordance with IEC 60204-1. |
| A19 | Input | DI5-SS1 NO | Safe stop digital input normally opened to +B (internal pull-down).<br>If the Safe Stop 1 function is enabled, closing the switch the inverter implements a safe stop of category 1 in accordance with IEC 60204-1. |
| A29 | Input | DI9-ALARM RESET | SS1-STO alarm reset digital input active when connected to +B (internal pull-down). Closing this switch and releasing the traction request, any alarm related to the SS1 and STO functions is reset. |
| A35 | Input | DI7-STO NO | Safe Torque Off digital input normally opened to +B (internal pull-down). |

| ACEX NEW GENERATION Foc3<br>Traction CAN operated premium configuration with encoder + STO and SS1 functions | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| | | | If the Safe Torque Off function is enabled, closing the switch the inverter implements a safe stop of category 0 in accordance with IEC 60204-1. |

### Premium version – PMSM traction CAN operated configuration with sin/cos sensor + STO and SS1 functions

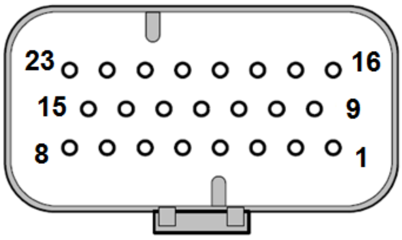
When the inverter is configured as premium BLEX NEW GENERATION for controlling a PM synchronous traction motor endowed with a sin/cos sensor, in a CAN operated configuration with safe stop 1 (SS1) and safe torque off (STO) functions, see paragraph 3.2.17, the pinout differs from that of the premium AC CAN operated traction configuration with encoder only for the pins listed in the following table. The other ones are unchanged both in name and in function.

| BLEX NEW GENERATION<br>Traction CAN operated premium configuration with sin/cos + STO and SS1 functions | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A13 | Input | SPARE | Spare digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up). No default function assigned. If FEEDBACK SENSOR (see paragraph 8.2.7) is set to 0, this pin is used as channel B of the incremental encoder. |
| A14 | Input | SPARE | Spare digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up). No default function assigned.<br>If FEEDBACK SENSOR (see paragraph 8.2.7) is set to 0, this pin is used as channel A of the incremental encoder. |
| A16 | Input | DI10-SS1 NC | Safe stop digital input normally closed to +B (internal pull-down). The input is activated when the external switch is opened.<br>If the Safe Stop 1 function is enabled, opening the switch the inverter implements a safe stop of category 1 in accordance with IEC 60204-1. |
| A17 | Input | DI8-STO NC | Safe torque off digital input normally closed to +B (internal pull-down). The input is activated when the external switch is opened.<br>If the Safe Torque Off function is enabled, opening the switch the inverter implements a safe stop of category 0 in accordance with IEC 60204-1. |
| A18 | Input | SIN | Sine signal of the sin/cos sensor.<br>If FEEDBACK SENSOR (see paragraph 8.2.7) is set to 0, this pin may be used as additional spare analog input with a voltage range 0 V ÷ 5 V. If not used must be grounded. |
| A19 | Input | DI5-SS1 NO | Safe stop digital input normally opened to +B (internal pull-down).<br>If the Safe Stop 1 function is enabled, closing the switch the inverter implements a safe stop of category 1 in accordance with IEC 60204-1. |

| BLEX NEW GENERATION<br>Traction CAN operated premium configuration with sin/cos + STO and SS1 functions | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A21 | Input | COS | Cosine signal of the sin/cos sensor.<br>If FEEDBACK SENSOR (see paragraph 8.2.7) is set to 0, this pin may be used as additional spare analog input with a voltage range 0 V ÷ 5 V. If not used must be grounded. |
| A29 | Input | DI9-ALARM RESET | SS1-STO alarm reset digital input active when connected to +B (internal pull-down). Closing this switch and releasing the traction request, any alarm related to the SS1 and STO functions is reset. |
| A35 | Input | DI7-STO NO | Safe Torque Off digital input normally opened to +B (internal pull-down).<br>If the Safe Torque Off function is enabled, closing the switch the inverter implements a safe stop of category 0 in accordance with IEC 60204-1. |

### 4.2.2 Standard Version

ACEX NEW GENERATION Foc3 Standard is equipped with a 23-poles Ampseal connector as shown in the figure below. Throughout this manual, each of the 23 pins is referred to as "A#", where "A" denotes the connector name and "#" the pin number, from 1 to 23.




*23-poles Ampseal connector of ACEX NEW GENERATION Foc3 standard version.*

*For each I/O pin has been specified the default type and functionality where available.*

*The I/O types and functionalities defined in the following inverter configurations are all available by default without any HW change, if not otherwise specified.*

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

*Any customization to the following configurations may require a new HW and/or SW release and must be discussed with Zapi in advance.*

### Standard version – ACIM traction configuration with encoder sensor

| ACEX NEW GENERATION Foc3<br>Traction standard configuration with encoder | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A1 | Output | NEVP1 | Driving output for a proportional electrovalve (driving to -B); PWM current controlled; 1.7 A maximum continuous current. The default PWM frequency is 1 kHz; different frequencies may be available on request. A dithering feature is also available, see paragraph 4.3.9. |
| A2 | Output | NEB | Driving output for the electromechanical brake (driving to -B); PWM voltage controlled; 2.5 A maximum continuous current. |
| A3 | Output | NENC | Negative reference for the motor feedback sensor, the thermal sensor and the potentiometers. |
| A4 | Input | CHB | Channel B of the incremental encoder. |
| A5 | Input | DI1-QI-PB | Digital input active when connected to +B (internal pull-down).<br>The default function is quick inversion or pedal brake. Closing the switch the quick inversion function is activated. |
| A6 | Output | PPOT2 | Positive supply for the potentiometers and/or for the motor feedback sensor. The default output voltage is +5 V, 140 mA maximum. +12 V is possible on request (HW customization). |
| A7 | Output | PENC | Positive supply for the motor feedback sensor and/or for the potentiometers. The default output voltage is +12 V, 200 mA maximum. +5 V is possible on request (HW customization). |
| A8 | Input | KEY | Input of the key switch signal. It is used to supply the logic section of the controller and the pre-charging circuit. |
| A9 | Input | CPOT1 | Analog input 1. The default function is as accelerator reference (wiper contact of the accelerator potentiometer). |
| A10 | Input | CHA | Channel A of the incremental encoder. |
| A11 | Input | DI0-SEAT | Digital input active when connected to +B (internal pull-down).<br>The default function is as presence input (seat or tiller). |
| A12 | Input | CUTBACK 1 | Digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up). The default function is as CUTBACK SPEED 1 input; when activated, the maximum speed is reduced in agreement with the CUTBACK SPEED1 parameter, see paragraph 8.2.1. To be exploited as additional analog input a hardware customization is required. |
| A13 | Input | THMOT | Analog input. Current-mode temperature sensing of the motor.<br>2 mA operation. Internally clamped to 5 V. |
| A14 | Input | DI6-LOWER | Digital input active when connected to +B (internal pull-down). The default function is as lowering request. Closing the switch, the proportional valve EVP1 is activated according to the set-point defined by the external potentiometer connected to A20. |

| ACEX NEW GENERATION Foc3<br>Traction standard configuration with encoder | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A15 | Input | DI7-LIFT | Digital input active when connected to +B (internal pull-down). The default function is as lift function; closing the switch the valve EV3 is activated. |
| A16 | Output | NLC | Driving output for the line – or main – contactor (driving to -B); PWM voltage controlled; 1.5 A maximum continuous current. |
| A17 | In/Out | CANL | Low-level CAN bus line. |
| A18 | In/Out | CANH | High-level CAN bus line. |
| A19 | Output | PEB | To be connected to the positive supply of the electromechanical brake and the electrovalves. The internal freewheeling diodes of the electromechanical brake and the electrovalves are connected to this pin. By default, the high side driver is not available in the standard configuration. It is available on request; HW customization. |
| A20 | Input | CPOT2 | Analog input 2. The default function is as breaking reference or as reference for the aperture of the proportional electrovalve EVP1, depending on the function being active.<br>If PEDAL BRK ANALOG = ON this input is used as analog brake input.<br>Otherwise, if AUX POT. TYPE is different from 12, this input is used as reference for the lowering proportional valve EVP1. |
| A21 | Input | DI-4BW | Digital input active when connected to +B (internal pull-down).<br>The default function is as backward request; closing this input the truck moves backward. |
| A22 | Input | DI3-FW | Digital input active when connected to +B (internal pull-down).<br>The default function is as forward request; closing this input the truck moves forward. |
| A23 | Output | NEV3 | Driving output for an auxiliary electrovalve (driving to -B); PWM voltage controlled; 1.5 A maximum continuous current. |

### Standard version – ACIM pump configuration with encoder sensor

When the inverter is configured as standard ACEX NEW GENERATION for controlling an AC pump motor endowed with an encoder, see paragraph 3.2.12, the pinout differs from that of the standard AC traction configuration with encoder sensor only for the pins listed in the following table. The other ones are unchanged both in name and in function.

| ACEX NEW GENERATION Foc3 – Pump standard configuration with encoder | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A1 | Output | NEVP1 | Driving output for a proportional electrovalve (driving to -B); PWM current controlled; 1.7 A maximum continuous current. The default PWM frequency is 1 kHz; different frequencies may be available |

| ACEX NEW GENERATION Foc3 – Pump standard configuration with encoder | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| | | | on request. A dithering feature is also available, see paragraph 4.3.9. Digital control mode only. The analog control mode is not available in this configuration. |
| A2 | Output | NEB | Driving output for an auxiliary electrovalve (driving to -B); PWM voltage controlled; 2.5 A maximum continuous current. |
| A5 | Input | DI1-SPEED1 | Digital input active when connected to +B (internal pull-down).<br>The default function is as 1ST pump motor speed; closing the switch the 1ST pump motor speed is selected, in agreement with the 1ST PUMP SPEED parameter. If present and enabled, closing the switch the valve EV1 is activated. |
| A9 | Input | CPOT1 | Analog input 1. The default function is as a reference for the lift pump motor (wiper contact of the lift potentiometer). |
| A12 | Input | SPARE | Spare digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up). No default function assigned. It may be used as a cutback upon a SW customization. |
| A14 | Input | DI6-SPARE | Spare digital input active when connected to +B (internal pull-down). No default function assigned.<br>It may be used as a HYDRO request upon a SW customization. |
| A15 | Input | DI7-SPEED3 | Digital input active when connected to +B (internal pull-down).<br>The default function is as 3ST pump motor speed; closing the switch the 3ST pump motor speed is selected, in agreement with the 3RD PUMP SPEED parameter. Closing the switch the valve EV3 is activated. |
| A19 | Output | PEB | To be connected to the positive supply of the auxiliary electrovalves. The internal freewheeling diodes of the electrovalves are connected to this pin. By default, the high side driver is not available in the standard configuration. It is available on request; HW customization. |
| A20 | Output | CPOT2 | Spare analog input 2. No default function assigned. |
| A21 | Input | DI4-LOWER | Digital input active when connected to +B (internal pull-down).<br>The default function is as lowering request; closing the switch the NEVP1 output is activated according to the MAX EVP parameter. |
| A22 | Input | DI3-LIFT | Digital input active when connected to +B (internal pull-down).<br>The default function is as lift request; closing this input the pump motor is activated. The motor speed is controlled with the lift potentiometer: input A9. |

### Standard version – PMSM traction configuration with sin/cos sensor

When the inverter is configured as standard BLEX NEW GENERATION for controlling a PM synchronous traction motor endowed with a sin/cos sensor, see paragraph 3.2.4 the pinout differs from that of the standard AC traction configuration with encoder only for the pins listed in the following table. The other ones are unchanged both in name and in function.

| BLEX NEW GENERATION – Traction standard configuration with sin/cos sensor | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A4 | Input | CUTBACK 1 | Digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up). The default function is as CUTBACK SPEED 1 input; when activated, the maximum speed is reduced in agreement with the CUTBACK SPEED1 parameter, see paragraph 8.2.1. |
| A10 | Input | LIFT | Digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up). The default function is as lift function; opening the switch the valve EV3 is activated. |
| A12 | Input | SIN | Sine signal of the sin/cos sensor |
| A15 | Input | COS | Cosine signal of the sin/cos sensor |

### Standard version – PMSM traction configuration with PWM sensor

When the inverter is configured as standard BLEX NEW GENERATION for controlling a PM synchronous traction motor endowed with a PWM sensor, see paragraph 3.2.6, the pinout differs from that of the standard AC traction configuration with encoder only for the pins listed in the following table. The other ones are unchanged both in name and in function.

| BLEX NEW GENERATION – Traction standard configuration with PWM sensor | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A4 | Input | SPARE | Spare digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up). No default function assigned. |
| A10 | Input | PWM | PWM signal of the PWM sensor |

### Standard version – PMSM traction configuration with 3-Hall sensors

When the inverter is configured as standard BLEX NEW GENERATION for controlling a PM synchronous traction motor endowed with three-Hall sensors, see paragraph 3.2.8, the pinout differs from that of the standard AC traction configuration with encoder only for the pins listed in the following table. The other ones are unchanged both in name and in function.

| BLEX NEW GENERATION – Traction standard configuration with 3-Hall sensor | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A4 | Input | SH2 | Input signal from the Hall sensor 2. |
| A10 | Input | SH3 | Input signal from the Hall sensor 3. |

| BLEX NEW GENERATION – Traction standard configuration with 3-Hall sensor | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A12 | Input | SH1 | Input signal from the Hall sensor 1. |

### Standard version – PMSM traction configuration with external resolver sensor interface

When the inverter is configured as standard BLEX NEW GENERATION for controlling a PM synchronous traction motor endowed with the external Zapi resolver interface, see paragraph 3.2.10, the pinout differs from that of the standard AC traction configuration with encoder sensor only for the pins listed in the following table. The other ones are unchanged both in name and in function.

| BLEX NEW GENERATION<br>Traction standard configuration with external resolver sensor interface | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A4 | Input | LIFT | Digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up). Opening the switch the valve EV3 is activated. |
| A6 | Output | PPOT2 | Positive supply for the resolver sensor interface and for the potentiometers. The default output voltage is +12 V, 200 mA maximum. +5 V is possible on request (HW customization). |
| A7 | Output | Pulse out | Digital output in the 0 - 5 V range. Driving output for the resolver interface digital input command pulse. |
| A10 | Input | Vfb | Analog input. The default function is as resolver excitation pulse voltage feedback, in the 0 - 5V range with 0V offset. |
| A12 | Input | SIN | Sine input signal from the external resolver interface. |
| A15 | Input | COS | Cosine input signal from the external resolver interface. |
| A23 | Output | NEV3 | Driving output for an auxiliary electrovalve (driving to -B); ON/OFF control mode only; 1.5 A maximum continuous current. |

### Standard version – ACIM traction CAN operated configuration with encoder sensor

When the inverter is configured as standard ACEX NEW GENERATION for controlling an AC traction motor endowed with an encoder sensor, in a CAN operated configuration, see paragraph 3.2.14, the pinout differs from that of the standard AC traction configuration with encoder only for the pins listed in the following table. The other ones are unchanged both in name and in function.

| ACEX NEW GENERATION Foc3 – Traction CAN operated standard configuration with encoder | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A2 | Output | NEB | Driving output for an auxiliary electrovalve (driving to -B); PWM voltage controlled; 2.5 A maximum continuous current. |
| A5 | Input | DI1-SPARE | Spare digital input active when connected to +B (internal pull-down). No default function assigned. |
| A9 | Input | CPOT1-SPARE | Spare analog input 1. No default function assigned. |
| A11 | Input | DI0-SPARE | Spare digital input active when connected to +B (internal pull-down). No default function assigned. |
| A12 | Input | DI11-SPARE | Spare digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up). No default function assigned. |
| A14 | Input | DI6-SPARE | Spare digital input active when connected to +B (internal pull-down). No default function assigned. |
| A15 | Input | DI7-SPARE | Spare digital input active when connected to +B (internal pull-down). No default function assigned. |
| A19 | Output | PEB | To be connected to the positive supply of the electrovalves. The internal freewheeling diodes of the electrovalves are connected to this pin. By default, the high side driver is not available in the standard configuration. It can be added on request; HW customization. |
| A20 | Input | CPOT2-SPARE | Spare analog input 2. No default function assigned. |
| A21 | Input | NODE ID0 | Digital input active when connected to +B (internal pull-down). The default function is as NODE ID0 selection. |
| A22 | Input | NODE ID1 | Digital input active when connected to +B (internal pull-down). The default function is as NODE ID1 selection. |

The default node identification number of the controller over the CAN bus is determined by the two NODE ID inputs as specified in the table below:

| NODE ID1 | NODE ID0 | CONTROLLER NODE ID |
|---|---|---|
| 0 | 0 | 8 |
| 0 | 1 | 10 |
| 1 | 0 | 12 |
| 1 | 1 | 14 |

By default, up to 4 different Zapi inverters can be identified over the CAN network.

### Standard version – ACIM traction CAN operated configuration with encoder sensor + STO or SS1 function

When the inverter is configured as standard ACEX NEW GENERATION for controlling an AC traction motor endowed with an encoder sensor, in a CAN operated configuration with safe stop 1 (SS1) or safe torque off (STO) function, see paragraph 3.2.16, the pinout differs from that of the standard AC CAN operated traction configuration with encoder only for the pins listed in the following table. The other ones are unchanged both in name and in function.

| **ACEX NEW GENERATION Foc3<br>Traction CAN operated standard configuration with encoder sensor + STO or SS1** | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A5 | Input | DI1-<br>STO/SS1<br>NO | Safe torque off / Safe stop 1 digital input normally opened to +B (internal pull-down).<br>If the Safe Stop 1 function is enabled, closing the switch the inverter implements a safe stop of category 1 in accordance with IEC 60204-1.<br>If the Safe Torque Off function is enabled, closing the switch the inverter implements a safe stop of category 0 in accordance with IEC 60204-1. |
| A11 | Input | DI0-<br>STO/SS1<br>NC | Safe torque off / Safe stop 1 digital input 2 normally closed to +B (internal pull-down). The input is activated when the external switch is opened.<br>If the Safe Stop 1 function is enabled, opening the switch the inverter implements a safe stop of category 1 in accordance with IEC 60204-1.<br>If the Safe Torque Off function is enabled, closing the switch the inverter implements a safe stop of category 0 in accordance with IEC 60204-1. |
| A14 | Input | DI6-<br>ALARM<br>RESET | SS1-STO alarm reset digital input active when connected to +B (internal pull-down). Closing this switch and releasing the traction request, any alarm related to the SS1 and STO functions is reset. |

### Standard version – PMSM traction CAN operated configuration with sin/cos sensor + STO or SS1 function

When the inverter is configured as standard BLEX NEW GENERATION for controlling a PM synchronous traction motor endowed with an sin/cos sensor, in a CAN operated configuration with safe stop 1 (SS1) or safe torque off (STO) function, see paragraph 3.2.18, the pinout differs from that of the standard AC CAN operated traction configuration with encoder only for the pins listed in the following table. The other ones are unchanged both in name and in function.

| **ACEX NEW GENERATION Foc3<br>Traction CAN operated standard configuration with encoder sensor + STO or SS1** | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A4 | Input | SPARE | Spare digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up). No default function assigned. If FEEDBACK SENSOR (see paragraph 8.2.7) is set to 0, this pin is used as channel B of the incremental encoder. |
| A5 | Input | DI1-<br>STO/SS1<br>NO | Safe torque off / Safe stop 1 digital input 1 normally opened to +B (internal pull-down). |

| ACEX NEW GENERATION Foc3<br>Traction CAN operated standard configuration with encoder sensor + STO or SS1 | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| | | | If the Safe Stop 1 function is enabled, closing the switch the inverter implements a safe stop of category 1 in accordance with IEC 60204-1.<br>If the Safe Torque Off function is enabled, closing the switch the inverter implements a safe stop of category 0 in accordance with IEC 60204-1. |
| A10 | Input | SPARE | Spare digital input inactive when connected to -BATT, active when the external switch is open (internal pull-up). No default function assigned.<br>If FEEDBACK SENSOR (see paragraph 8.2.7) is set to 0, this pin is used as channel A of the incremental encoder. |
| A11 | Input | DI0-STO/SS1 NC | Safe torque off / Safe stop 1 digital input 2 normally closed to +B (internal pull-down). The input is activated when the external switch is opened.<br>If the Safe Stop 1 function is enabled, opening the switch the inverter implements a safe stop of category 1 in accordance with IEC 60204-1.<br>If the Safe Torque Off function is enabled, closing the switch the inverter implements a safe stop of category 0 in accordance with IEC 60204-1. |
| A12 | Input | SIN | Sine signal of the sin/cos sensor |
| A14 | Input | DI6-ALARM RESET | SS1-STO alarm reset digital input active when connected to +B (internal pull-down). Closing this switch and releasing the traction request, any alarm related to the SS1 and STO functions is reset. |
| A15 | Input | COS | Cosine signal of the sin/cos sensor |

## 4.3 External devices

### 4.3.1 Key input

KEY input A10 (A8) is generally connected to the vehicle start key switch. It supplies the battery voltage to the logic circuitry and it also pre-charges the DC-link capacitors at key-on, before the main contactor closes. The KEY voltage is monitored via hardware and software.

*Note: external loads connected to the power terminal +B and not driven by the inverter, such as proximity switches or cooling fans, may overload the internal PTC resistor along the KEY input path slowing-down the pre-charge of the DC-link capacitors. An excessive pre-charge delay may lead the inverter in an alarm state.*

### Protection

The KEY input is protected against reverse polarity and against ESD. The ESD protection is ensured via an internal capacitor to -B plus other filtering elements. This capacitance can cause a current spike at key-on.

We recommend the usage of an external fuse (FU1 in the functional drawings, see paragraphs 3.2.1 ÷ 3.23.2.18) in series with the KEY input. A 10 A fuse is recommended, nevertheless, fuse FU1 should be sized according to the number of motor controllers connected to the key switch and their current absorption at the KEY input. In all the ACEX NEW GENERATION Foc3 inverter configurations the input power measured at KEY input never exceeds 10 W.

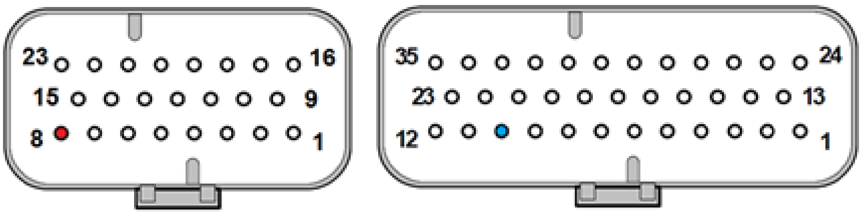
⚠ ***The key switch connected to the KEY input must handle the short inrush current spike to the ESD protection capacitors. The current peak depends on the external circuit and cabling.***

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

⚠ ***The key switch must guarantee electric continuity at light load conditions (less than 500 mA). Electric drops longer than 2 ms on the key input may lead the inverter in alarm conditions.***

### Connector position

Standard A8 | Premium A10




## 4.3.2 Digital inputs

Digital inputs are meant to work in the voltage range from -B to the overvoltage threshold specified in chapter 2.4. Related command devices (microswitches) must be connected to +B (typically to the key voltage) or to -B, depending on the input configuration (refer to the connection drawings in the paragraph 3.2). Pull-down or pull-up resistors are built-in.

Application functionalities (like forward, backward, lowering etc…) are normally open so that each associated function becomes active when the corresponding microswitch closes. Instead, safety-related functions must be normally closed, so that each associated function becomes active when the corresponding microswitch opens.

The nominal voltage and thresholds for digital inputs in the Zapi configurations are listed in the table below. On request, custom hardware may feature different voltage values.

| **Nominal inverter voltage** | | **24 V** | **36/48 V** | **72/80 V** |
|---|---|---|---|---|
| **Close to +B (internal PD) Active high** | $V_{IL\_MAX}$ | 3.6 V | 3.6 V | 8.3 V |
| | $V_{IH\_MIN}$ | 8.5 V | 8.5 V | 19.4 V |

| Nominal inverter voltage | | 24 V | 36/48 V | 72/80 V |
|---|---|---|---|---|
| Close to -B (internal PU) Active low | $V_{IL\_MAX}$ | 3.6 V | 3.6 V | 3.7 V |
| | $V_{IH\_MIN}$ | 8.5 V | 8.5 V | 8.7 V |
| Cutback1 (internal PU) Active high. On A18/A12 | $V_{IL\_MAX}$ | 4.50 V * | 4.50 V * | 4.50 V * |
| | $V_{IH\_MIN}$ | 4 V * | 4 V * | 4 V * |
| Cutback2 (internal PU) Active high. When A21 | $V_{IL\_MAX}$ | 10.8 V * | 10.8 V * | 11 V * |
| | $V_{IH\_MIN}$ | 9.8 V * | 9.8 V * | 10.2 V * |
| Cutback1 (internal PU) Active high. On A13/A4 | $V_{IL\_MAX}$ | 3.5 V | 3.5 V | 3.5 V |
| | $V_{IH\_MIN}$ | 1.5 V | 1.5 V | 1.5 V |
| Cutback2 (internal PU) Active high. On A14 | $V_{IL\_MAX}$ | 3.5 V | 3.5 V | 3.5 V |
| | $V_{IH\_MIN}$ | 1.5 V | 1.5 V | 1.5 V |
| Lift (internal PU) Active high. On A10 or A4 | $V_{IL\_MAX}$ | 3.5 V | 3.5 V | 3.5 V |
| | $V_{IH\_MIN}$ | 1.5 V | 1.5 V | 1.5 V |
| Voltage range | | 0 ÷ 35 V | 0 ÷ 72.5 V | 0 ÷ 115 V |

*The voltage thresholds marked with the * symbol can be changed with a software customization.*

***For critical safety related 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 is protected against ESD events.

### Circuit

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

| Nominal Inverter voltage | 24 V | 36/48 V | 72/80 V |
|---|---|---|---|
| Input impedance Close to +B (internal PD) Active high | 15 kΩ | 22 kΩ | 56 kΩ |
| Input impedance Close to -B (internal PU) Active low | 4.7 kΩ | 4.7 kΩ | 4.7 kΩ |
| Input Impedance Cutback1, 2 (internal PU) Active high. On A13/A4, A14 | 3.3 kΩ | 3.3 kΩ | 3.3 kΩ |
| Input Impedance Cutback1, 2 (internal PU) Active high. On A18/A12, A21 | 4.7 kΩ | 4.7 kΩ | 4.7 kΩ |

*NENC on A5 (A3) is the preferred negative reference for those digital inputs to be closed to -BATT.*

*Digital inputs on A1 (A11), A6, A7 (A5), A16, A17, A19, A20 (A14), A29, A31 (A21), A32 (A22) and A35 (A15) are normally configured to be activated when closed or opened to +B. Their behavior can be changed by special HW configuration, as to be activated when closed to -B.*

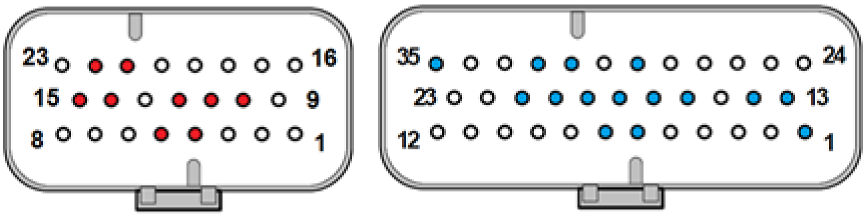
*A13 (A4) and A14 (A10) can be exploited as encoders inputs or as digital inputs normally closed to -B (cutback 1 and cutback 2), depending on the input configuration (refer to the connection drawings in the paragraph 3.2).*

*A18 (A12) and A21 (A15) can be exploited as sin/cos inputs, as additional analog inputs or as additional digital inputs normally closed to -B (cutback 1 and cutback 2), depending on the input configuration (refer to the connection drawings in the paragraph 3.2).*

**Connector position**

Standard
A4, A5, A10, A11, A12,
A14, A15, A21, A22

Premium
A1, A6, A7, A13, A14, A16,
A17, A18, A19, A20, A21,
A29, A31, A32, A35




**Microswitches**

- It is suggested to use microswitches with a contact resistance lower than 0.1 Ω and a leakage current lower than 100 μA.
- If the microswitches to be adopted have different specifications, it is suggested to discuss them with Zapi technicians prior to employ them.

### 4.3.3 Encoder and 3-Hall sensor inputs

Encoder and three-Hall sensor inputs for motor-speed and position feedback have an internal 3.3 kΩ pull-up for open collector sensor output. Threshold levels in the Zapi configurations are listed below. Custom hardware may feature different values.

| Speed-sensor supply voltage | 5 V | 12 V |
|---|---|---|
| $V_{IL\_MAX}$ | 3.40 V | 3.40 V |
| $V_{IH\_MIN}$ | 1.3 V | 1.3 V |

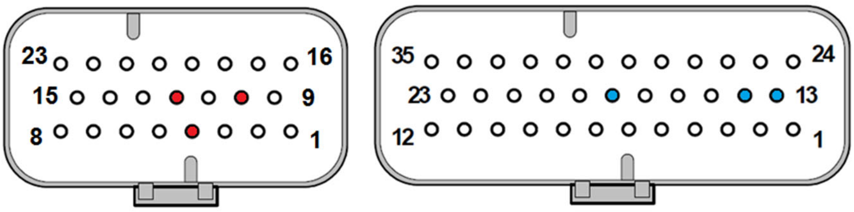
Speed-sensor signals are acquired via the quadrature peripheral of the microcontroller.

### Protection

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

### Connector position

Standard A10, A4, A12 | Premium A13, A14, A18




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

For more details about encoder installation see also 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 8.2.7.*

*When not connected to the speed motor feedback sensor, A13 (A4), A14 (A10) and A18 (A12), can be exploited as additional digital inputs normally closed to -B.*

*The default input bandwidth of these signals is 20 kHz. Any higher bandwidth requires a hardware customization.*

## 4.3.4 PWM sensor input

PWM sensor input for motor-speed and position feedback has an internal 680 Ω pull-up for open collector sensor output. Threshold levels in standard Zapi configurations are listed below. Custom hardware may feature different values.

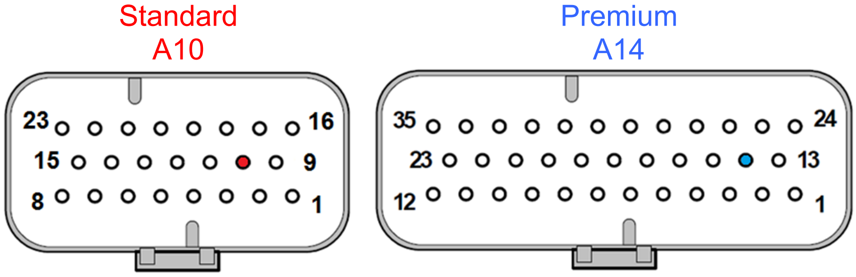
| **Speed-sensor supply voltage** | **5 V** | **12 V** |
|---|---|---|
| $V_{IL\_MAX}$ | 3.45 V | 3.45 V |
| $V_{IH\_MIN}$ | 1.47 V | 1.47 V |

The PWM signal is acquired via the capture/compare unit of the microcontroller.

### Protection

This input is protected against short circuits to +B and -B and have ESD suppressor to -B for ESD protection (IEC/EN 61000-4-2 level 4).

**Connector position**




> ⚠ ***It is important to optimize the wiring for ensuring that PWM signal is not disturbed by motor currents or by the electric motor brake.***

> *When not connected to the speed/position motor feedback sensor, A14 (A10) can be exploited as additional digital inputs normally closed to -B.*

### 4.3.5 Analog inputs

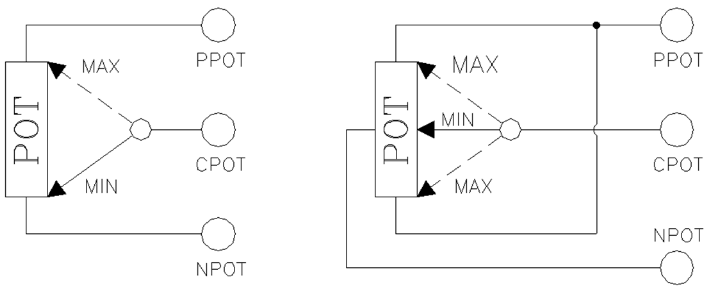
Analog inputs A15 (A9) and A30 (A20) can be exploited as accelerator or brake references and they are acquired through a 10-bit analog-to-digital converter (the resolution is given by voltage excursion over 1024 levels).

**Circuit**

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

| Inverter voltage | 24 V | 36/48 V | 72/80 V |
|---|---|---|---|
| **Input DC impedance** | 47 kΩ | 47 kΩ | 120 kΩ |
| **Maximum frequency** | 33 Hz | 33 Hz | 13 Hz |
| **Input linear range** | 0 ÷ 10.2 V | 0 ÷ 10.2 V | 0 ÷ 10.2 V |

The standard connection for the potentiometer is that on the left-hand side of next figure: potentiometer at rest at one end, in combination with a couple of travel-demand switches. On request, it is also possible to find the configuration on the right-hand side of the figure: potentiometer at rest in the middle, still in combination with a couple of travel-demand switches.




*Potentiometer configurations.*

A procedure for automatic acquisition of potentiometers signals is available via the Zapi CAN console (see paragraphs 9.1, 9.2, 9.3 and 9.4) after having chosen the correct configuration through the appropriate parameter.

The negative supply of the potentiometers has to be taken from NENC A5 (A3).

The potentiometers can by supplied via the pin PENC A25 (A20) or PPOT2 A8 (A6). Potentiometer resistance value should be in the range 0.5 – 10 kΩ.

On request, analog inputs may also be used as extra digital inputs (a software customization is necessary). In this case, the ADC value is used as the indicator of the input status. For example, a proximity switch supplied from +B could be connected to an analog input.

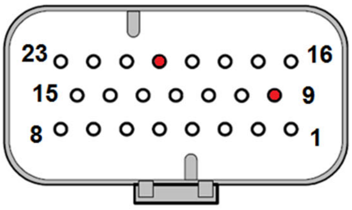
**Protection**

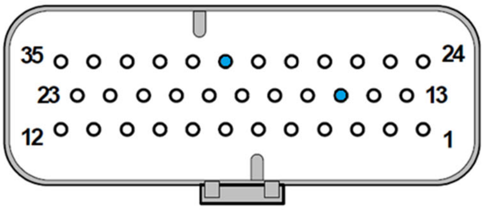
Analog inputs are protected against short circuits to +B and -B and against ESD events.

**Connector position**

Standard
A9, A20

Premium
A15, A30




*When not connected to the speed/position motor feedback sensor, A18 (A12) and A21 (A15) can be exploited as additional analog inputs.*

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

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

### 4.3.6 SIN/COS sensor inputs

Sine A18 (A12) and cosine A21 (A15) sensor input for motor-speed and position feedback are acquired through a 10-bit analog-to-digital converter and the input impedance and the maximum frequency for analog inputs in standard Zapi configurations are listed below. Custom hardware may feature different values.

| **Inverter voltage** | **24 V** | **36/48 V** | **72/80 V** |
|---|---|---|---|
| **Input DC impedance** | 47 kΩ | 47 kΩ | 120 kΩ |
| **Maximum frequency** | 3.3 kHz | 3.3 kHz | 4 kHz |
| **Input linear range** | 0 ÷ 5 V | 0 ÷ 5 V | 0 ÷ 5 V |

The sin/cos motor speed and position sensor can by supplied via the pin PENC A25 (A20) or PPOT2 A8 (A6).

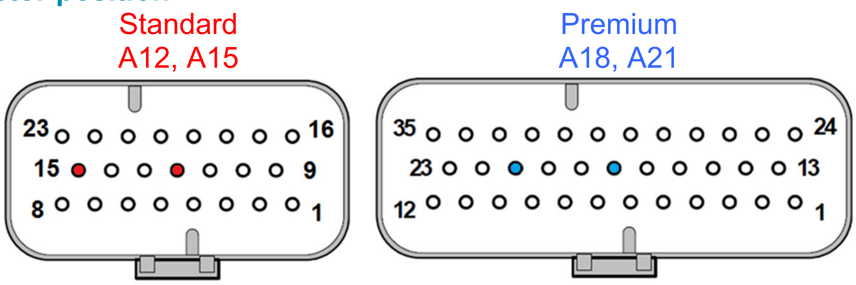
The negative supply of the sin/cos sensor is provided through the NENC pin A5 (A3).

A procedure for automatic acquisition of the absolute sensor is available via the Zapi pc CAN console.

**Protection**

These inputs are protected against short circuits to +B and -B and have ESD suppressor to -B for ESD protection (IEC/EN 61000-4-2 level 4).

**Connector position**




*A18 (A12) and A21 (A15) can be exploited as additional analog inputs to read potentiometers signals in the range 0 ÷ 5 V.*

*In certain Zapi configurations, A18 (A12) and A21 (A15) can be exploited as additional digital inputs normally closed to -B (cutback 1 and cutback 2).*

*These analog inputs may also be used as active high digital inputs upon a hardware customization. In this case the ADC value should be used as the indicator of the input status. For example, a proximity switch supplied from +B could be connected to an analog input.*

### 4.3.7 MC output

Main (or line) contactor is operated through an open-drain PWM-voltage-controlled output on pin A12 (A16).

By default, in order to utilize the built-in freewheeling diode, the coil must be supplied using the KEY voltage, pin A10 (A8), see chapter 3.2.

A non-standard hardware configuration permits to utilize a built-in freewheeling diode connected to pin PEB A2 (A19).

In case the vehicle design does not allow usage of the built-in freewheeling diode, i.e. if the return path integrity cannot be guaranteed in all situations, an external one must be applied between 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 hardware 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 with software customizations. 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 A10 (A8) and ESD protected by means of an ESD-suppressing device. Protected against reverse polarity of the battery.

Built-in diagnostics:
- Overcurrent
- Driver shorted
- Driver open
- Coil open

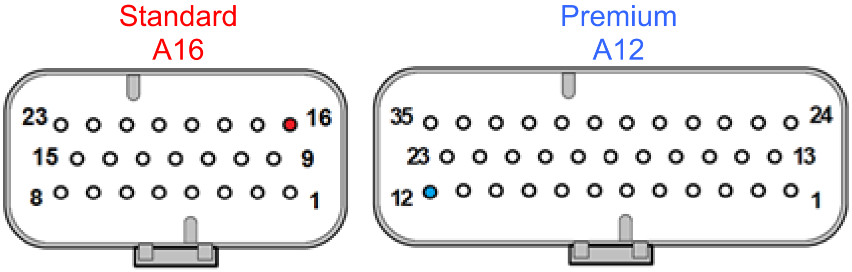
Refer to chapter 10 for more detailed description.

*Overcurrent protection is featured by hardware. In case of overcurrent, the software enters an alarm state and opens the main contactor.*

*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 controller from overvoltage caused by an inductive load, a freewheeling diode to pin KEY A10 (A8) is built-in.***

***Please ensure that inductive loads are connected so that the paths through the freewheeling diodes are always present; otherwise use external freewheeling diodes.***

***Use of brushless fan or other loads with built-in capacitors may lead to high inrush currents at turn-on, which may eventually trip an overcurrent alarm. Inrush current must be below the peak current.***

### 4.3.8 EB output

Electromechanical brake is operated through an open-drain PWM-voltage-controlled output on pin NEB A4 (A2). In the premium configurations, in order to utilize the built-in freewheeling diode, the coil must be supplied by pin PEB A2 which in turn is supplied by a high-side driver (see paragraph 4.3.10). In the standard configurations that does not foresee the internal high side driver circuit, the supply of the electromechanical brake can be taken downstream of the line contactor and the return path of the freewheeling current is still provided through the PEB pin A19.

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, external freewheeling diodes must be applied over the inductive loads supplied by the open drain output.

#### Output features

- Up to 2.5 Arms continuous current (holding).
- Up to 3 A peak (pulling) current for a maximum of 200 ms.
- Dedicated hardware for the detection of: shorted driver, open driver, open coil.
- 1 kHz PWM default frequency.
- 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 brake or hydraulic valves.*

---

#### Protection

Protected against inductive discharge with internal freewheeling diode to pin PEB A2 (A19) and ESD protected by suppressor device (IEC/EN 61000-4-2 level 4).

Not directly protected against reverse polarity of the battery. Nevertheless, a way to avoid a failure caused by the polarity inversion is to activate the contactor only once the voltage over the DC-bus capacitors has reached the accepted pre charge level.

Built-in diagnostics:

- Overcurrent
- Driver shorted
- Driver open
- Coil open

---

*Overcurrent protection is implemented in hardware.*

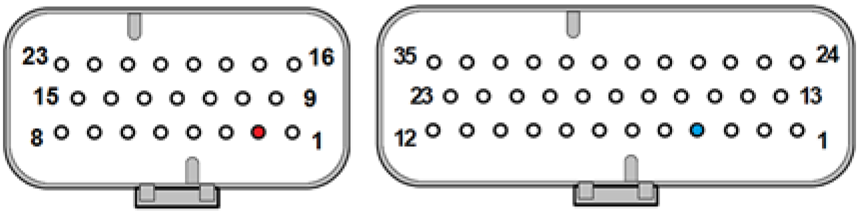
*EB output can be only a PWM voltage-controlled output. It cannot be used as current-controlled output.*

*If the electromechanical brake is not present, upon a software customization, NEB can be exploited as a general purpose open-drain PWM voltage controlled output.*

---

***When driving an inductive load there must be a path for the current through a freewheeling diode. Do not connect any switch or fuse in series with the freewheeling diode.***

**Connector position**




***To protect the motor controller from an overvoltage caused by an inductive load, an internal freewheeling diode to pin A2 (A19) is built-in.***

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

***Use of brushless fan or other loads with built-in capacitors may lead to high inrush currents during the driver turn-on which may eventually trip an overcurrent alarm. Inrush current must be below the peak current.***

### 4.3.9 Auxiliary Outputs

Open-drain outputs A8 (A6), A9 (A7), A11, A23, A24 (A1), A26, A33 (A23) and A34 can be used for operating relays, hydraulic valves, horn, fans, and similar services.

The supported working modes are:

- ON/OFF (NEV5)
- PWM voltage controlled (NEV1, NEV2*, NEV3*, NEV4, NEV6)
- PWM current controlled (NEVP1, NEVP2)

* In combination with a resolver interface, NEV2 is exploited for the excitation of the resolver; NEV3 is only available as an ON/OFF output.

In the Zapi premium configuration, the positive supply of the electrovalves is connected downstream the line contactor and the freewheeling current path is close through the built-in diodes to the pin PEV A3.

In the Zapi standard configuration, the positive supply of the electrovalves is connected downstream the line contactor and the freewheeling current path is close through the built-in diodes to the pin PEB A19.

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 over the inductive loads supplied by the open drain outputs.

### ON/OFF outputs

- Individual 1.5 Arms maximum continuous (hold) current and 2 A peak current for a maximum duration of 200 ms.
- Individual hardware for detection of shorted driver, open driver and open coil.

### PWM voltage-controlled outputs

- Individual 1.5 Arms maximum continuous (hold) current and 2 A peak current for a maximum duration of 200 ms.
- Individual hardware for detection of shorted driver, open driver and open coil.
- 1 kHz PWM frequencies.
- The duty cycle of each PWM voltage controlled outputs can be modified with separate software parameters.

### PWM current-controlled outputs

- 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.
- The default PWM frequency is 1 kHz. PWM frequency can be changed with software customizations. If a different PWM frequency has to be used, it is suggested to discuss it with Zapi technicians.
- 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 to prevent it from “sticking”. Successful dithering improves the valve response for small changes.

  Dithering frequency (in Hz) is available in fixed steps:
  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. Actual dithering amplitude is dependent on load inductance.

### Protection

The auxiliary outputs are protected against inductive discharge with internal freewheeling diodes, as described above, and against ESD events (IEC/EN 61000-4-2 level 4).

The auxiliary outputs are not directly 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 over the DC-bus capacitors has reached the accepted pre charge level (see picture in section 3.2).

NEV1, NEV2, NEV3, NEV4 and NEV6 auxiliary outputs are endowed with these built-in diagnostics:

- Shorted driver
- Open driver
- Open coil

Refer to chapter 10 for more details about alarms.

The electrovalves EV1, EV2, EV3, EV4, EV5 and EV6 have a common overcurrent protection circuit; the overall continuous current limit is 6 A.

---

*In the Zapi configurations pin A8 (A6) is exploited to supply the motor speed/position sensor and the potentiometers. In order to exploit A8 (A6) as an additional open-drain output, a hardware customization is necessary.*

*NEV5 auxiliary output, when available, has these built-in diagnostics: shorter driver and open driver. It is not able to detect an open coil.*

*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, EV4, EV5 and EV6 outputs.*

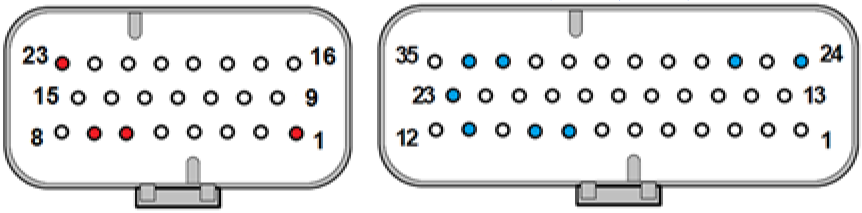
*In certain configurations, some of the PWM voltage controlled outputs support the ON/OFF control mode only. Please, refer to your configuration described in chapters 4.2.1 or 4.2.2 for further details.*

---

### Connector position

Standard
A1, A6, A7, A23

Premium
A8, A9, A11, A23,
A24, A26, A33, A34

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***The maximum total continuous current when multiple EV outputs are active at the same time is 6 A. The maximum total peak current is 7 A.***

***When driving inductive loads on PWM 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 diodes.***

***To protect the motor controller from an overvoltage caused by an inductive load, an internal freewheeling diode to pin A3 (A19) is built-in.***

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

---

***Use of brushless fan or other loads with built-in capacitors may lead to high inrush currents during the driver turn-on which may eventually trip an overcurrent alarm. Inrush current must be below the peak current.***

### 4.3.10 High-side driver

In premium configurations, the high-side switch provides redundancy in turning off the EB and eventually the EVs in safety critical applications. If one of the open-drain outputs supplied by PEB is short circuited, it is possible to turn off the high-side switch in order to disconnect the loads connected to pin A2 (PEB) from the positive supply.
The high-side switch has a maximum output current of 4 A. The high-side switch can only be controlled as an on/off switch, it does not suit for switching operations.

#### Protection

Built-in diagnostics:

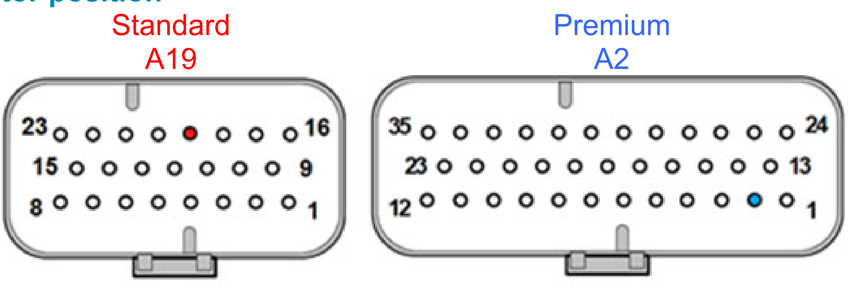
- Shorted driver
- Open driver
- PEB shorted to -B

Refer to chapter 10 for more detailed description.

*In the Zapi premium configurations, the high side driver switch is supplied by pin A3 PEV. In order to supply the high side driver from the key input A10, a hardware customization is necessary.*

*In the Zapi standard configurations, the high side driver switch is not present. The return paths of the freewheeling currents are provided through the PEB pin A19 that is connected downstream the line contactor. On request, upon a hardware customization, it is possible to add the high side driver switch to the standard configurations. In this case, the preferred high side driver supply pin would be the key input A8, or as an alternative, pin A1, that can be configured as PEV renouncing to the PWM current-controlled output NEVP1.*

#### Connector position




***The maximum total continuous current when the electromechanical brake and multiple electrovalves are supplied by PEB is 4 A. The maximum total peak current (less than 2 s) is 6 A.***

***In certain configurations the high side driver may not be assembled but the PEB A2 (A19) pin can be exploited as a return path for the freewheeling currents of the built-in diodes of the electromechanical brake and multiple electrovalves. In this case, the maximum total RMS freewheeling current allowed is 6 A.***

### 4.3.11 Motor-temperature measurement

The motor-temperature sensing, for measuring the temperature of motor windings, is available on pin THMOT A22 (A13).
Pin NENC A5 (A3) provides the negative reference for the motor thermal sensor.
Compatible temperature sensors are:

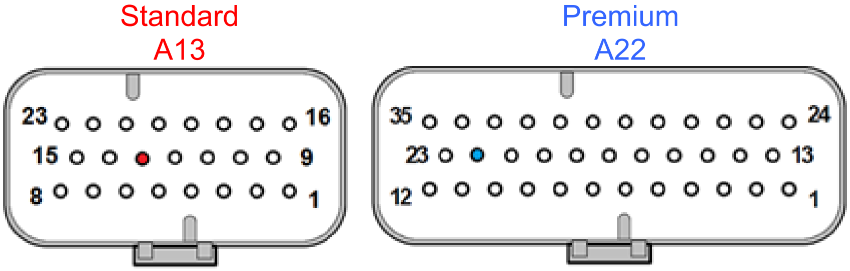
- KTY84 with 1000Ω @ 100°C.
- KTY83 with 1670Ω @ 100°C.
- PT1000 with 1385Ω @ 100°C.
- On/Off.

The built-in current-mode temperature sensing circuit drives 2 mA through the external sensor and it monitors the voltage level at pin A22 (A13).

#### Protection

THMOT input is protected against short circuits to +B, -B and it is protected against ESD events (IEC/EN 61000-4-2 level 4). The built-in low-pass filter attenuates the noise from the motor.

#### Connector position




### 4.3.12 Sensor supply

Supply for external motor-speed and position sensor is available between pin PENC A25 (A7) and pin NENC A5 (A3).
Output voltage is configurable via hardware by internal jumper to +12 V or +5 V. The default value is +12 V. The maximum output current is 200 mA.

*On pin PENC A25 (A7) +5 V is available on request; a hardware customization is necessary.*

*Pin PENC A25 (A7) can be used also to supply potentiometers and other external analog sensors.*

*All the Zapi premium configurations foresee two supplies for external motor-speed and analog devices: pin PENC A25 whose default voltage is +12 V, and pin PPOT2 A8 whose default voltage is +5 V.*

*On request, in the standard configurations, the pin PENC A7 can be exploited as open drain output to drive the electrovalve EV1. In this case, the external motor-speed sensor, potentiometers, and external analog devices are all supplied via the pin PPOT2 A6.*

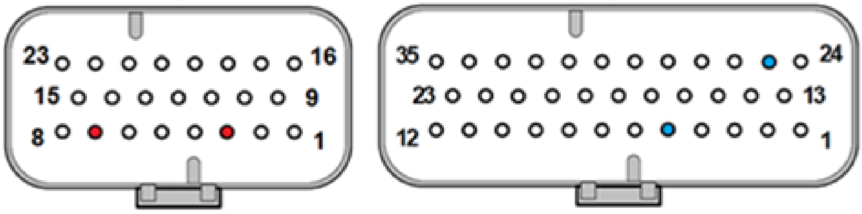
*If both pin PENC A25 (A7) and pin PPOT2 A8 (A6) are configured to supply +12 V then the maximum output current of both of them is reduced to 100 mA.*

**Protection**

Sensor supply is protected against accidental connection to +B.

**Connector position**

Standard A3, A7 | Premium A5, A25




***Please ensure that adequate loads have been connected to pin PENC A25 (A7) before to switch on the key; the maximum continuous current must be limited to 200 mA.***

***If you have a Zapi premium or standard configuration do not connect a +5 V motor-speed position sensor to this pin. +5 V on this pin is available only upon a hardware customization.***

### 4.3.13 Analog supply

Supply for external analog sensors and analog speed or brake potentiometers is available between pin PPOT2 A8 (A6) and pin NENC A5 (A3).

Output voltage is configurable via hardware by internal jumper to +12 V or +5 V. The default output voltage is +5 V for all the Zapi premium configurations and for the Zapi standard configurations that foresee the +12 V PENC function on pin A7. The maximum output current is 140 mA.

*Pin PPOT2 A8 (A6) can be used to supply the motor-speed and position sensor when +5 V is required.*

*All the Zapi premium configurations foresee two supplies for external motor-speed and analog devices: pin PENC A25 whose default voltage is +12 V, and pin PPOT2 A8 whose default voltage is +5 V.*

*In the Zapi standard configurations where pin PENC A7 is used as open drain output to drive the electrovalve EV1, the external motor-speed sensor, the potentiometers and analog devices are all supplied via the pin PPOT2 A6 that has a default voltage of +12 V. In these configurations +5 V is available only via a hardware customization.*

*If both pin PENC A25 (A7) and pin PPOT2 A8 (A6) are configured to supply +5 V then the maximum output current of both of them is reduced to 70 mA.*

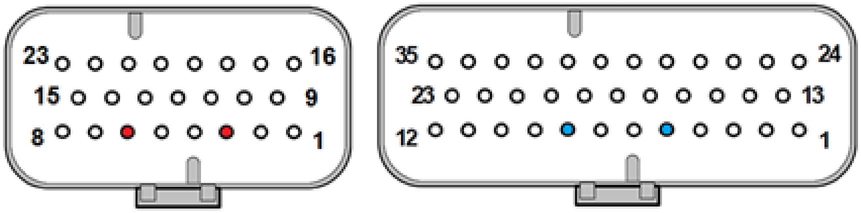
**Protection**

Analog supply is protected against accidental connection to +B.

**Connector position**

Standard
A3, A6

Premium
A5, A8




***Please ensure that adequate loads have been connected to pin PPOT2 A8 (A6) before to switch on the key; the maximum continuous current must be limited to 140 mA.***

***If you have a Zapi standard configuration that foresees a +12 V output voltage on pin PPOT2 A6, then do not connect a +5 V motor-speed position sensor to this pin.***

### 4.3.14 CAN bus

A non-isolated CAN bus interface is available for communication with the controller, featuring:

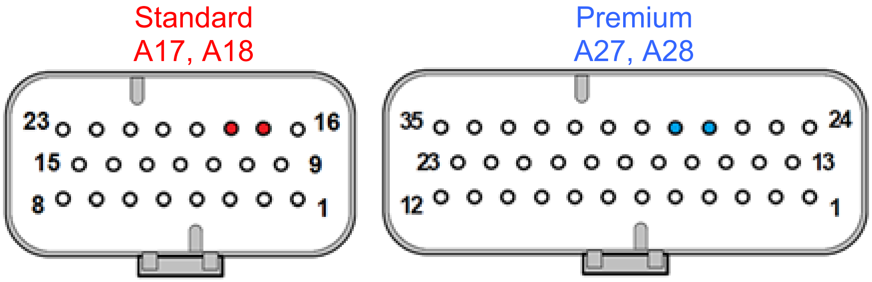
- Communication physical layer according to ISO 11898-2
- Selectable data rate up to 1Mbit/s.
- The inverter features an internal 120 Ω termination resistor on request. By default the internal termination resistor is not assembled.
- An internal common-mode filter can be assembled on request.
- The CAN bus negative reference is the -BATT voltage. Nevertheless, to reduce the noise introduced by the power section, the pin NENC A5 (A3) can be used as a negative reference.

The CAN transceiver and the common mode noise filter ensure an adequate differential output voltage swing and a common mode noise immunity at the same time.

**Protection**

CAN bus interface is protected against ESD events and against overvoltage and accidental connections to +BATT and -BATT.

**Connector position**




*In a non-isolated CAN bus line configuration, the negative reference for the devices exchanging information via CAN bus is the -BATT. Please refer to paragraph 6.2.4 for more installation hints.*

*CAN-cabling shall use a pair of twisted wires for CANH and CANL wires.*

*The CAN wiring shall have a characteristic impedance of 120 Ω and both the physical ends of the CAN bus shall be terminated with a 120 Ω resistor between CANH and CANL to achieve the best noise immunity and performances.*

# 5 FEATURES

## 5.1 Operational features

- Speed control (three versions available: sensored, sense coil and sensorless, as explained in the introduction section) or torque control available.
- Electrical stop-on-ramp: the machine is electrically held in place for a programmable time.
- Stable speed in every position of the accelerator.
- Regenerative release braking based upon deceleration ramps.
- Direction inversion with regenerative braking based upon deceleration ramp.
- The release braking ramp can be modulated by an analog input, so that a proportional brake feature is obtained.
- Optimum sensitivity at low speeds.
- Voltage boost at the start and with overload to obtain more torque (with current control).
- Driver for predefined and generic outputs: main contactor, electromechanical brake, auxiliary loads.
- Hydraulic steering function:
  - When ACEX NEW GENERATION Foc3 works as traction inverter: the traction inverter sends a "hydraulic steering function" request to the pump inverter on the CAN bus line.
  - When ACEX NEW GENERATION Foc3 works as pump inverter: the pump inverter manage a hydraulic steering function, which is it drives the pump motor at the programmed speed for the programmed time.
- High efficiency of motor and battery due to the high frequency commutations.
- 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).
- Internal hour-meter with values that can be displayed on 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. After the speed demands have been generated, the operation of each motor controller falls back to the case of a single traction motor.

## 5.3 Pump motor

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.

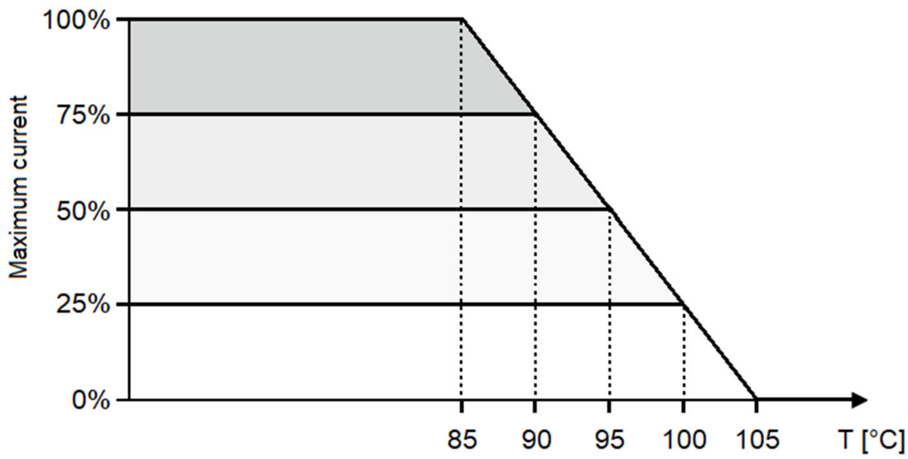
## 5.5 Torque mode

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 provides a driving experience like 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

ACEX NEW GENERATION Foc3 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.
- **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.
- **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.
- **Low battery charge**
  When the battery charge is low, the maximum current is reduced to half of the maximum current programmed.




*Thermal cutback.*

– **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.

– **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.***

# 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 5.6 Nm ÷ 8.4 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

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, lift-up or disable the driving wheels to prevent the possibility of unexpected vehicle motion or motion in the wrong direction during the 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 and to prevent injuries to personnel and/or 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.***

### 6.2.1 Positioning and cooling of the controller

- If the controller is equipped with the base plate mounting:

- Anchor it on a flat, clean and unpainted metallic surface to maximize the heat dissipation.
    - Unless the surface where the controller will be anchored is very smooth, it is better to apply a light layer of thermo-conductive grease between the two surfaces to improve the heat dissipation.
    - Ensure that the compartment that hosts the controller is adequately ventilated and that the ambient temperature does not exceed the ambient operating temperature indicated in chapter 2.2. Otherwise, the inverter current rating reduces.
- If the controller is equipped with the heat sink, the customer shall ensure an adequate air flow within the fins to match the continuous rated current specified in paragraph 2.3. Abnormal ambient temperatures should be considered.
- The thermal power to be dissipated varies with the current drawn and with the duty cycle.
- Ensure that the cable terminals and connectors are correctly connected and the vehicle wiring complies with the connection drawings of paragraph 3.2.

***Hot surfaces - risk of personnel injury. After operation of the motor controller, the heat sink may be hot. Do not perform any maintenance when hot.***

### 6.2.2 Dust and liquid ingress prevention

The dust/moisture protection of the motor controller is only valid when the mating I/O connector is inserted and correctly 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 must not be subjected to liquids under high pressure.

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

### 6.2.3 Power cables

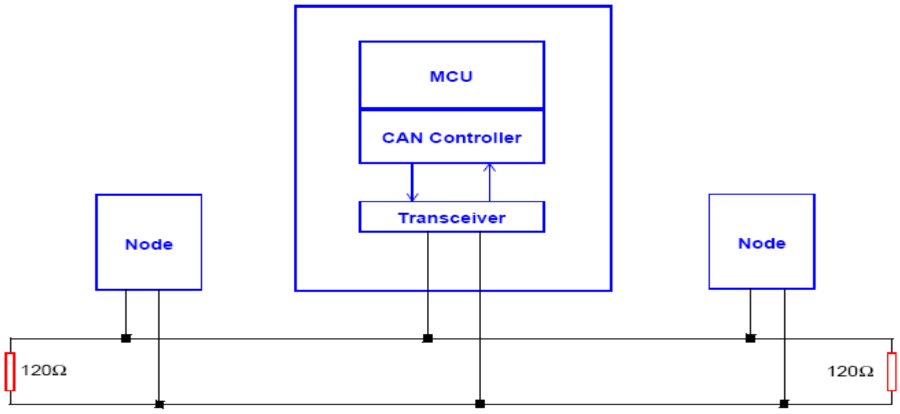
- Power connections to the motor and from the battery: use cables having a proper section.
- Power cables must be as short as possible to minimize power losses.
- Power lugs must be tightened onto the controller power posts with a torque in the range 5.6 Nm ÷ 8.4 Nm.
- Positive and negative cables from the battery should run side by side. Try to avoid power cables loops.
- The ACEX NEW GENERATION Foc3 controller shall be connected to a traction battery. Do not use converters outputs or other power supplies. For special applications please contact the Zapi technicians or your sales manager of reference.

***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 correct operation of the controller.***

***Ring lugs for motor and battery connections must be adequately rated to carry motor and battery currents. Otherwise, cables and terminal posts may be overheated.***

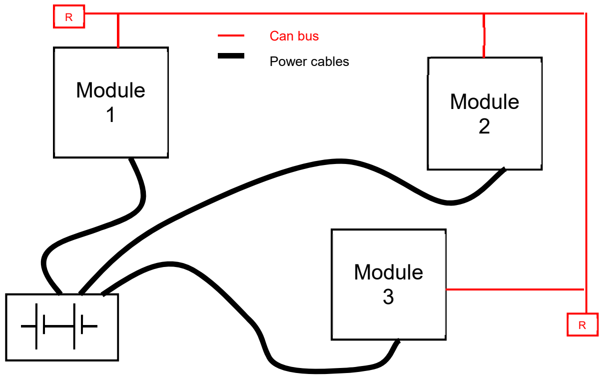
### 6.2.4 CAN bus

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.



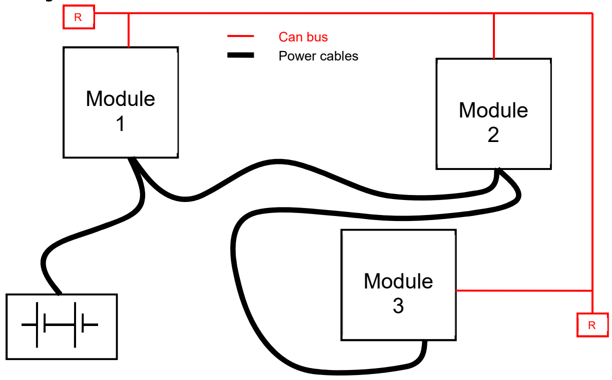

The best type of cables for CAN bus connections is the twisted pair; if it is necessary to increase the immunity of the system to disturbances, a good choice would be to use shielded cables, where the shield is connected to the frame of the truck. Sometimes it is sufficient a not shielded two-wire cable 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.

***Star 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.
The best solution depends on the type of nodes (modules) connected in the network. In case the nodes draw almost the same power, the star topology is a good layout. If the modules are very different in terms of power, then the preferable connection is the daisy chain.

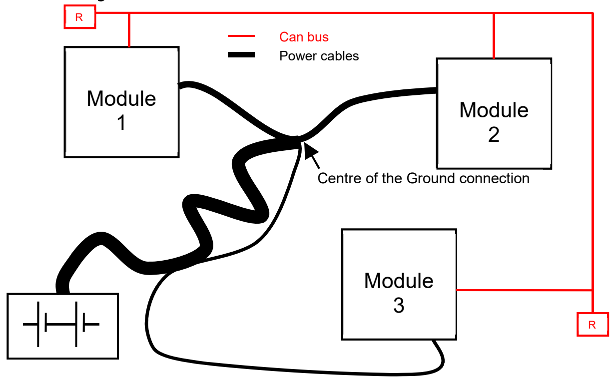
***Daisy chain layout:***




***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 between the high current modules, as shown in the next figure.

***Star layout with star center between the high-current modules.***




***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 also the diameter of the cables contributes to the voltage drops and ground bounce (a greater diameter brings to a lower impedance), so 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 ground bounce problems and considering the current drawn from the battery by the overall system.

*The CAN bus addresses the complexity of modern systems where lot of data and information must be exchanged between different nodes in the system:*
*- simple design (readily available, multi sourced components and tools)*
*- low costs (less and smaller cables)*
*- high reliability*
*- facilitate the debug and interconnection analysis (with a PC it is possible to monitor real-time the data being transferred onto the bus).*

### 6.2.5 I/O connections

- For the auxiliary circuits, use cables of 0.5 mm² section.
- After crimping the cable, verify that all strands are entrapped in the wire barrel.
- Verify that all the crimped contacts are completely inserted on the Ampseal connector cavities.
- Where built-in freewheeling diodes cannot be exploited to recirculate the current of inductive loads (solenoids, horns and others), be sure that external suppression devices and freewheeling diodes have been installed.
- For information about pin assignment, see chapter 3.2.
- When high-currents circulate between motor controller and battery, there may be voltage differences between the -B references of the different inverters installed in the system. Therefore, it is strongly recommended to supply all the sensors linked to a motor controller directly with its intended power pins.
- Try to isolate EMC sensitive connections from noisy I/O cables.

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

### 6.2.6 Motor feedback sensors

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.***

***Make sure that the feedback sensor 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

ACEX NEW GENERATION Foc3 can handle different types of encoder. The incremental encoder speed sensor provides speed and direction feedback for the motor controller. The standard speed encoder switches two open collector outputs to produce two square wave signals phase shifted 90 ° ±45 ° (see Figure 16), with a maximum frequency of 20 kHz. The sensor signals must have a minimum 6μs edge separation. The motor controller can be configured to accept 32 – 160 pulses/revolution.

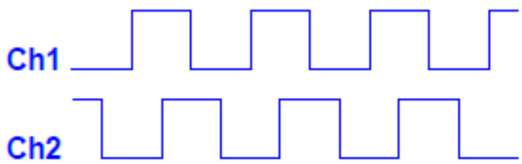



*Figure 16. Incremental speed encoder signals*

Depending on the hardware configuration that is going to be installed, the +12 V power rail or both the +12 V and +5 V power rails are available to supply the encoder. For special applications it is possible to install an incremental encoder with the zero-position signal. Encoders with a push-pull output stage are supported.

| | | |
|---|---|---|
| A25/A8 (A6) | +12V/+5V | Positive power supply |
| A5 (A3) | GND | Negative power supply |
| A14 (A10) | ENC A | Phase A |
| A13 (A4) | ENC B | Phase B |
| A18 (A12) | Z POS | Z-index |

⚠ ***OEMs shall specify in the commercial order the type of encoder used, in terms of power supply and electronic outputs, so that the controller can be properly configured by Zapi.***

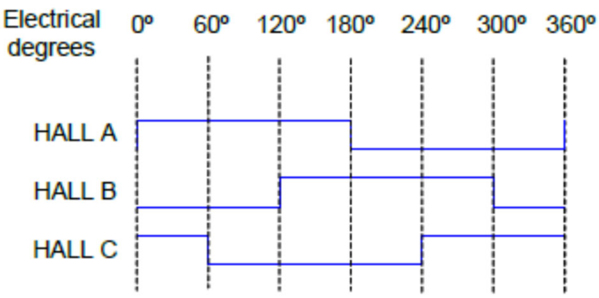
⚠ ***The number of pulses per revolution can be properly set on the field using the dedicated parameters (see paragraph 8.2.7).***

⚠ ***The maximum speed detectable by Zapi hardware configuration can be limited depending on the number of pulses/rev. Contact Zapi technicians for checking this aspect.***

⚠ ***It is strongly suggested, for safety reasons, to lift the wheels from the floor and set the correct value according to the type of sensor used prior to perform any operation with the truck.***

### Six-step encoder signals

When the PMSM is of the BLDC type, it must be controlled with a six-step inverter (trapezoidal waves). A PMSM is a BLDC when, by turning its shaft, the electromotive force between two motor terminals is of trapezoidal shape. To control BLDC motor with Zapi inverter, a six-step encoder (3-Hall sensors) can be employed. The six-step encoder, for DC brushless motors, provides position, speed and direction feedback for the motor controller. The six-step encoder switches three open collector outputs to produce a three-phase square wave output for six-step commutation timing, phase shifted 120 ° ±15 °, as shown in the figure below.




*Six-step encoder signals*

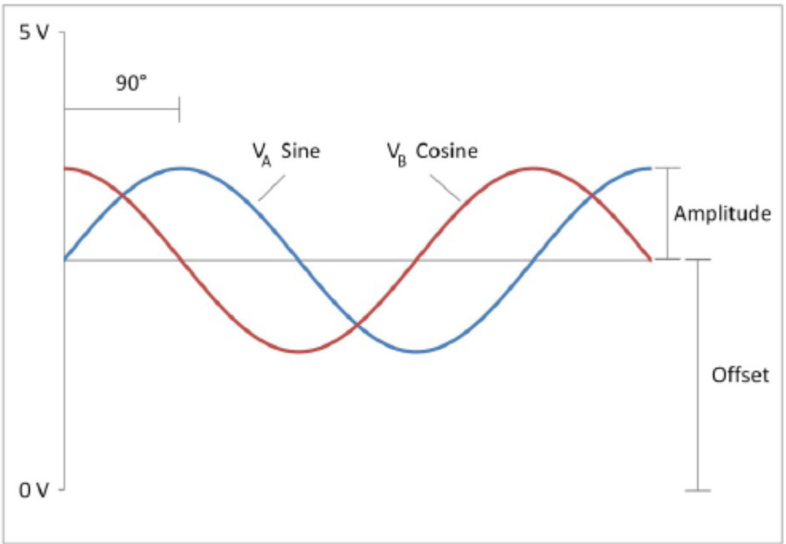
The motor controller can be configured to operate DC brushless motors with 2–10 poles. The six-step encoder interface is available in both the premium and the standard versions. The six-step encoder sensor signals are connected to the encoder CHA, CHB and CHC (or Z) inputs and the sensor is supplied using the same sensor supply pins as the incremental encoders (depending on the hardware configuration can be +12 V or +5 V).

| | | |
|---|---|---|
| A25/A8 (A6) | +12V/+5V | Positive power supply |
| A5 (A3) | GND | Negative power supply |
| A14 (A10) | SH3 | Hall sensor 3 |
| A13 (A4) | SH2 | Hall sensor 2 |
| A18 (A12) | SH1 | Hall sensor 1 |

***Since the logic unit and the software must be set in the correct way by Zapi, it is absolutely mandatory to specify in the commercial order the type of Hall sensors used (in terms of supply voltage, output voltage and number of pulses per revolution), their configuration in the d-axis rotor orientation and their sequence around one turn.***

### Sinusoidal motor speed sensor

When the PMSM is of the BLAC type (when turning its shaft it produces sinusoidal electromotive force at its terminals), it is necessary to install an absolute sin/cos sensor. This sinusoidal sensor for synchronous motors provides position, speed and direction feedback for the motor controller. At the first key-on, an auto-teaching procedure has to be performed so to acquire the sensor signals in terms of offset and amplitude and the mechanical offset between the sensor itself and the motor stator. Moreover, dynamic offset and gain adjustments (individual for each channel) are done in software to compensate for minor changes in sensor characteristics due to temperature, supply voltage and aging. The sinusoidal analog sensor produces a single-ended two-phase sinusoidal wave output as shown in the figure below.




*Sinusoidal analog sensor signal*

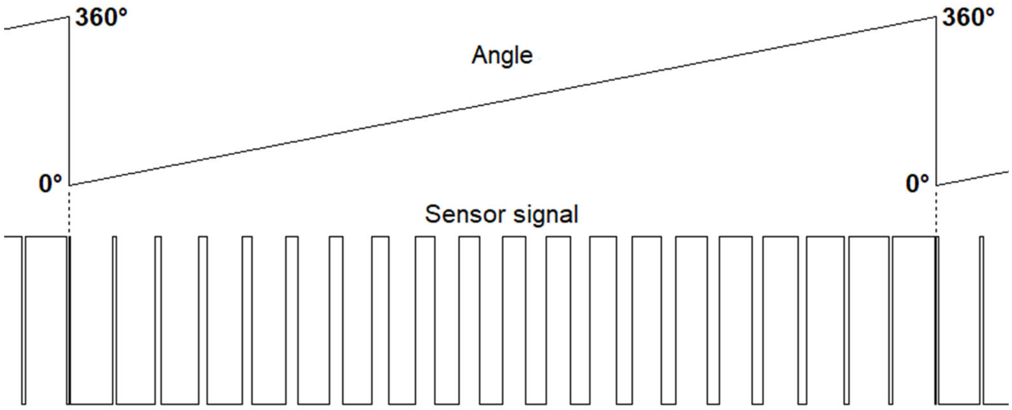
The sin/cos interface is available for both the premium and standard versions. For the connection of the sine and cosine signals and the sensor power supply refer to the functional drawing described in the paragraphs 3.2.3 and 3.2.4.

| | | |
|---|---|---|
| A25/A8 (A20/A6) | +12V/+5V | Positive power supply |
| A5 (A3) | GND | Negative power supply |
| A18 (A12) | SIN | Sensor sine signal |
| A21 (A15) | COS | Sensor cosine signal |

It is necessary to specify the type of sensor used in terms of power supply, electronic output and number of periods per revolution, because the logic unit and the software must be set in the correct way by Zapi.

### PWM absolute position sensor

PWM absolute position and speed sensor can replace the sin/cos sensor when the PMSM is of the BLAC type (when turning its shaft it produces sinusoidal electromotive force at its terminals). PWM is a way of digitally encoding analog signal levels as shown in the figure below.




*PWM sensor signal vs angle evolution.*

The PWM absolute sensor provides position, speed and direction feedback to the motor controller. The maximum frequency of the PWM sensor signal is 20 kHz.
The PWM sensor interface is available in both the premium and the standard versions. The PWM sensor signal is connected to the encoder CHA input pin; for the connection of the PWM signal and the sensor power supply refer to the functional drawing described in the paragraphs 3.2.5 and 3.2.6.

| | | |
|---|---|---|
| A25/A8 (A20/A6) | +12V/+5V | Positive power supply |
| A5 (A3) | GND | Negative power supply |
| A14 (A10) | PWM | Sensor PWM signal |

***It is necessary to specify the type of sensor used in terms of power supply, electronic output and number of pulses per revolution, because the logic unit and the software must be set in the correct way by Zapi.***

## 6.2.7 Motor temperature sensor

A temperature sensor with a positive temperature coefficient embedded in the motor winding provides a means for the motor controller to monitor the motor temperature. The motor temperature is used by the software in the vector control algorithms, and can also be used to protect the motor from overheating reducing the current flowing in the motor winding.
The motor controller can be configured to operate with different sensors such as KTY 83, KTY 84, PT1000 and similar.

*__Installation of the motor temperature sensor is done by the motor manufacturer. Contact the motor manufacturer to get the correct wiring. If the temperature sensor cables are not connected with the right polarity, the sensor acquisition may not be correct and the over-temperature protection of the motor will not work properly.__*

### 6.2.8 Main contactor and key switch

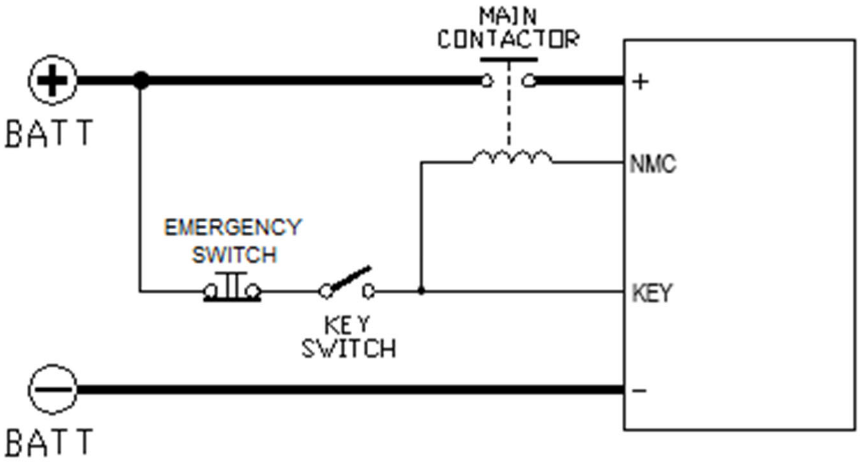
The connection of the battery line switches must be carried out following instructions from Zapi.

*__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.__*

*__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.__*

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.




*Typical connection of the main contactor, the key switch and the emergency button.*

For safety reasons, an emergency button shall be installed upstream of the key switch for cutting off at the same time the supply to the inverter and the positive supply of the excitation coil of the main contactor in emergency situations.
Supplying the excitation coil as depicted in the image above ensures that the main contactor will open together with the emergency switch, regardless of the status of the motor controller.
During regenerative braking, the battery voltage may rise above the operational threshold; an intrinsic protection is present against battery voltages above 140% of the nominal one.
The output driving the main contactor coil is modulated with a 1 kHz PWM; to reduce the overheating of the main contactor coil is strongly suggested to reduce

the PWM duty cycle reducing the percentage set in the MC VOLTAGE RED parameter. Indeed, after an initial delay of about 1 second, during which the coil is driven with a VBATT percentage defined by the MC VOLTAGE parameter, the PWM reduces the mean voltage down to the percentage set in MC VOLTAGE RED.

### 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

⚠ ***When installing a Zapi control, special attention must be paid to lengths, paths and shielding of the electric connections; EMC and ESD performances of an electronic system are strongly influenced by its installation in the field. Zapi can offer assistance and suggestions on EMC related problems, given its extensive experience in motor control applications. However, <u>ZAPI declines any responsibility for non-compliance, malfunctions and failures due to a wrong installation. The machine validation, based on existing norms (EN12895 for industrial truck; EN50081-2 for other applications), is under the responsibility of the machine manufacturer.</u>***

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, or *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 in 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 operation 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, to 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 high-speed serial communication channels used to transfer critical information between several intelligent nodes installed in the truck.
   - 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 failure can vary from a temporary malfunction to a permanent failure of the electronic device.

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***IMPORTANT NOTE**: often, it is easier and cheaper to avoid ESD from being generated, rather than increasing the level of immunity of the electronic devices.*

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There are different solutions to EMC issues, depending on the required level of emissions/immunity to be achieved, the type of controller, materials and machine wiring.

1) EMISSIONS. Three ways can be followed to reduce the emissions:
   - SOURCE OF EMISSIONS: identify the main source of disturb and work on it.
   - SHIELDING: enclose the contactor and the controller in a shielded box and usage of 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 that 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 HINTS

The motor controller is a software configurable device.

In a CAN supervisor system, some or all aspects of the motor controller setup and operation may be managed by a vehicle master controller device communicating with the motor control via the CAN bus. In a standalone installation, a customized software release may be installed in the motor controller in order to handle the necessary I/O.

Built-in diagnostic functions monitor the battery voltage, the inverter temperature, the motor temperature, and other conditions. Error and warning information are available to the master controller, and all event information is stored in an event log for service access (see chapter 10).

The event log provides additional information as well as procedures for pinpointing and eliminating causes of warning and error conditions.

## 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 from the nominal value indicated on the controller label.***

⚠ ***Take necessary precautions for not compromising the safety and in order to prevent injury to personnel or damage to equipment.***

⚠ ***All motor controller settings and functionality have to be verified and validated by the OEM prior the usage in the field by the end user. The complete range of parameter values downloaded in the truck controller (or any other device) must also be verified and validated prior the usage in the field by the end user. During the preliminary tests, while the parameter values are under validation, it is of major importance to take proper safety precautions since an incorrect parameter set may compromise the truck's safety critical functions.***

⚠ ***It is the OEMs responsibility to ensure that the vehicle is configured and set up in compliance with the required safety regulations.***

⚠ ***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.***

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 shown in the product identification label.
3. Verify that the correct software for the application has been loaded.
4. Verify that all power and signal wires are correctly connected.
5. Verify that battery and motor terminals are tightened with appropriate torque.
6. Verify that the I/O plug (Ampseal connector) is fully mated and latched in position on the motor controller.
7. Verify that the motor controller is properly protected with fuses. Refer to the vehicle maintenance documentation for the correct fuse size.

## 7.2 Set-up procedure for AC traction inverter

Normally, motor controllers shipped to OEM for series production are programmed by production lines with the correct parameters 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 the possibility of re-programming the motor controller via the CAN bus.

The basic set-up procedure for ACEX NEW GENERATION Foc3 inverter in traction configuration is listed below. It can be carried out using the Zapi PC CAN Console or the Zapi Smart Console.
If you need to replicate the same set of settings on different controllers, use the SAVE and RESTORE sequence; otherwise go down the following sequence.

- 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.
- 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 slightly move when the drive request is active. Increase the level accordingly.
- Set the speed reduction as required by your specifications (see parameter HB ON / SR OFF in list SET OPTIONS).

- Set the other performance-related parameters such as RELEASE BRAKING, INVERS. BRAKING, DECEL. 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 the operative conditions (with and without load, on flat and on ramp, etc.).

### 7.2.1 Acquisition of absolute position sensors

In addition to the steps listed above, the acquisition of the absolute position sensor (sin/cos, six step, PWM or resolver) is necessary for controlling a synchronous motor. 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 the synchronous motor for the first time.

---

*An automatic acquisition procedure is available. It has to be activated only once at commissioning. Please, contact the Zapi technicians to receive detailed information about how to run the automatic 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 necessary 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, the recorded data are discarded and the inverter has to be reset. Please, contact the Zapi technicians for any trouble.*

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## 7.3 Set-up procedure for AC pump inverter

The basic set-up procedure for the ACEX NEW GENERATION Foc3 inverter in pump configuration is very similar to the set-up procedure for the traction inverter.

- Under ADJUSTMENT, 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 maximum current for lift and lowering in MAX. CURRENT TRA and MAX. CURRENT BRK (see paragraph 8.2.1).
- Set the motor-related parameters. It is suggested to discuss them with Zapi technicians.
- Set parameter SET MOT.TEMPERAT according to the type of motor thermal sensor adopted.
- Set the acceleration delay (ACCEL MODULATION and ACCELER. DELAY parameters). Test the behavior in both directions.
- Set the FREQUENCY CREEP starting from 0.3 Hz. The pump should slightly run when the request is active. Increase the level accordingly.

- Set the other performance-related parameters such as MAX SPEED LIFT, 1ST SPEED, 2ND SPEED, 3RD SPEED, 4RD SPEED, 5TH SPEED.
- Set the parameters related to hydraulic steering, such as HYD SPEED FINE and HYDRO TIME.
- Test the pump in all operative conditions (with and without load, etc.).

At the end of your modifications, cycle the key switch to make them effective.

# 8 PROGRAMMING & ADJUSTEMENTS

The ACEX NEW GENERATION Foc3 software provides to the end-user application a large number of parameters necessary to grant the fine control of all the inverter features. To access and adjust all inverter parameters it is necessary to use the Zapi console. Since the ACEX NEW GENERATION Foc3 has no external serial connector, three possibilities are available:

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

Zapi Smart Console and PC CAN Console software are tools developed to improve the setup and programming of all Zapi products installed in any application.
It features a clean and easy-to-use interface in order to simplify access to parameters and troubleshooting.
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 set. This procedure is easy to do thanks to the Zapi Smart Console (see section 13.2) or thanks to the PC CAN Console (see section 13.1).
- Inside the saved copy or in a related text file write down the reason of the changes.
- Change the parameters with full knowledge of what you are doing.
- After having saved the new parameters, check that all parameters have been loaded in the inverter according to your modifications by reading back the value stored inside the parameters.

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

## 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.
- 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
- CTB. STEER ALARM
- 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
- MIN EVP2
- MAX EVP2
- EVP2 OPEN DELAY
- EVP2 CLOSE DELAY

### 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

### 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
- EMERGENYC INPUT
- SYNCRO
- AUTO PARK BRAKE
- ACCEL MODULATION
- EVP TYPE
- EVP2 TYPE
- EV1
- EV2
- EV3
- EV4
- EV5
- EV6
- 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

### ADJUSTMENTS

- 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 EV1
- PWM EV2
- PWM EV3
- PWM EV4
- PWM EV5
- PWM EV6
- MAX. MOTOR TEMP.
- STOP MOTOR TEMP.
- MOT.T. T.CUTBACK
- VACC SETTING

### SPECIAL ADJUSTMENTS

- ADJUSTMENT #01
- ADJUSTMENT #02
- CURR. SENS. COMP
- CURR. FALLBACK
- SET CURRENT
- SET TEMPERATURE
- HW BATTERY RANGE
- DUTY PWM CTRAP
- ADJUSTMENT #03
- SET CURRENT PUMP
- PWM AT LOW FREQ
- PWM AT HIGH FREQ
- FREQ TO SWITCH
- DITHER AMPLITUDE
- DITHER FREQUENCY
- CAN BUS SPEED
- DEBUG CANMESSAGE
- 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
- SAFETY DEBUG
- HW EXTENSION

### 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

### HARDWARE SETTINGS

- TOP MAX SPEED
- CONF.POSITIVE LC
- POSITIVE E.B.

### HYDROSETTINGS

- HYDRO TIME
- HYDRO FUNCTION

### FEEDBACK SENSOR

- ROTATION CW ENC
- ROTATION CW MOT
- ROTATION CW POS
- FEEDBACK SENSOR
- FEEDBACK POLES
- ENCODER PULSES 1
- ENCODER PULSES 2
- MOTOR P. PAIRS 1
- MOTOR P. PAIRS 2
- DIAG.JUMP SENSOR
- A.SENS.MAX SE
- A.SENS.MIN SE
- A.SENS.MAX CE
- A.SENS.MIN CE
- OFFSET ANGLE
- HYST. ANGLE
- SENSOR ANGLE DEL
- RESOLVER PULSE
- ABS.SENS. ACQ.ID
- ABS.SENS.ACQUIRE

### 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

*Please, note that the final subset of these parameters that is active and therefore visible on the Zapi Smart Console and PC CAN Console depends on the controller type, motor type and the feedback sensor selected.*

## 8.2 Settings description

The aim of this paragraph is to describe all the inverter parameters. For each one will be specified the name, the allowable range and a brief description as shown below.

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

In the "Parameter" column, the availability field (between brackets) lists the controller types where the parameter is available. The controller type acronyms used to fill in the "Availability" field are:

- **A =** All controller types
- **T =** Traction controller (in single-motor applications)
- **TM =** Traction master controller (in multi-motor applications)
- **TS1 =** Traction slave controller number 1(in multi-motor applications)
- **TS23 =** Traction secondary controller number 2 and 3 (multi-motor applications)
- **P =** Pump controller
- **CO =** CAN-operated controller
- **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 refer to the Zapi standard software. They could be different in any other customized software release, depending on customer's requests.*

### 8.2.1 PARAMETER CHANGE

| PARAMETER CHANGE | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **ACC. TORQUE DEL.**<br>(T, TM, P, CO, G, TS23, MCO) | 0.1 s ÷ 10 s<br>(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.<br>With TORQUE CONTROL = OFF, i.e. when the speed control is active, the speed ramps during accelerations can be subject to limitations due to too slow torque ramps. With TORQUE CONTROL = OFF, it is suggested to leave this parameter to the default value of 0.1 s. |
| **DEC. TORQUE DEL.**<br>(T, TM, P, CO, G, TS23, MCO) | 0.1 s ÷ 10 s<br>(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.<br>In case TORQUE CONTROL = OFF, i.e. when the speed control is active, the speed ramps during decelerations can be subject to limitations due to too slow the torque ramps. With TORQUE CONTROL = OFF, it is suggested to leave this parameter to the default value of 0.1 s. |
| **ACCELER. DELAY**<br>(T, TM, P, CO, G, MCO) | 0.1 s ÷ 25.5 s<br>(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.<br>The acceleration rate is computed depending on the speed change, as per the strategy described in paragraph 9.5 Acceleration modulation. |
| **RELEASE BRAKING**<br>(T, TM, P, CO, G, MCO) | 0.1 s ÷ 25.5 s<br>(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.<br>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**<br>(T, TM, P, CO, G, MCO) | 0.1 s ÷ 25.5 s<br>(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.<br>The deceleration rate is computed depending on the speed change, as per the strategy described in paragraph 9.6 Deceleration modulation. |
| **TILLER BRAKING**<br>(T, TM, CO, MCO) | 0.1 s ÷ 25.5 s<br>(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.<br>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** |
| **INVERS. BRAKING**<br>(T, TM, CO, MCO, G) | 0.1 s ÷ 25.5 s<br>(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.<br>The deceleration rate is computed depending on the speed change, as per the strategy described in paragraph 9.6 Deceleration modulation. |
| **DECEL. BRAKING**<br>(T, TM, CO, MCO, G, P) | 0.1 s ÷ 25.5 s<br>(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.<br>The deceleration rate is computed depending on the speed change, as per the strategy described in paragraph 9.6 Deceleration modulation. |
| **PEDAL BRAKING**<br>(T, TM, CO, MCO, G) | 0.1 s ÷ 25.5 s<br>(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.<br>The stopping rate is computed depending on the starting speed, as per the strategy described in paragraph 9.7 Release modulation. |
| **SPEED LIMIT BRK.**<br>(T, TM, P) | 0.1 s ÷ 25.5 s<br>(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.<br>The deceleration rate is computed depending on the speed change, as per the strategy described in paragraph 9.6 Deceleration modulation. |
| **STEER BRAKING**<br>(T, TM) | 0.1 s ÷ 25.5 s<br>(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.<br>The deceleration rate is computed depending on the speed change, as per the strategy described in paragraph 9.6 Deceleration modulation. |
| **SS1 BRAKING**<br>(CO) | 0 ÷ 50 | This parameter defines the braking ramp for the safety function SS1 (safe stop 1), featured by the CAN operated versions of the controller. |
| **GSS1 BRK. TIME**<br>(CO) | 0 ÷ 100 | This parameter defines the maximum braking time for the GSS1 function (guaranteed safe stop 1) featured by the CAN operated versions of the controller. |

| PARAMETER CHANGE | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **ACC. MIN MODUL.**<br>(T, TM, CO, MCO, G, P) | 1% ÷ 100%<br>(steps of 1%) | This parameter defines the minimum speed set-point variation for the acceleration modulation to have effect, provided that ACCEL MODULATION = ON. Variations of the speed set-point smaller than ACC. MIN MODUL. result in accelerations proportionally shorter than time ACCELER. DELAY.<br>It is expressed as a percentage of 100 Hz, which is the maximum speed set-point variation for the acceleration modulation to have effect.<br>The default value is 8%.<br>See parameters ACCEL MODULATION under SET OPTIONS, ACCELER. DELAY under PARAMETER CHANGE and paragraph Acceleration Modulation (9.5). |
| **REL. MIN MODUL.**<br>(T, TM, CO, MCO, G, P) | 1% ÷ 100%<br>(steps of 1%) | This parameter defines the minimum speed set-point variation for the braking modulation to have effect in release. Variations of the speed set-point smaller than REL. MIN MODUL. result in decelerations proportionally shorter than time RELEASE BRAKING.<br>It is expressed as a percentage of 100 Hz, which is the maximum speed set-point variation for the braking modulation to have effect.<br>The default value is 30%.<br>See parameter RELEASE BRAKING and paragraph 9.7 Release modulation. |
| **MAX SPEED FORW**<br>(T, TM) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the maximum speed in forward direction as a percentage of TOP MAX SPEED. |
| **MAX SPEED BACK**<br>(T, TM) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the maximum speed in backward direction as a percentage of TOP MAX SPEED. |
| **MAX SPEED LIFT**<br>(P) | 0% ÷ 100%<br>(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**<br>(P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the speed of the pump motor when $1^{st}$ speed is requested. It represents a percentage of the maximum pump speed. |
| **2ND PUMP SPEED**<br>(P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the speed of the pump motor when $2^{nd}$ speed is requested. It represents a percentage of the maximum pump speed. |
| **3RD PUMP SPEED**<br>(P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the speed of the pump motor when $3^{rd}$ speed is requested. It represents a percentage of the maximum pump speed. |
| **4TH PUMP SPEED**<br>(P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the speed of the pump motor when $4^{th}$ speed is requested. It represents a percentage of the maximum pump speed. |
| **5TH PUMP SPEED**<br>(P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the speed of the pump motor when $5^{th}$ speed is requested. It represents a percentage of the maximum pump speed. |

| PARAMETER CHANGE | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **HYD PUMP SPEED**<br>(P) | 0% ÷ 100%<br>(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**<br>(T, TM, P) | 20% ÷ 100%<br>(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**<br>(T, TM, P) | 20% ÷ 100%<br>(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**<br>(T, TM) | 10% ÷ 25%<br>(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**<br>(T, TM) | 0% ÷ 100%<br>(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**<br>(T, TM) | 0% ÷ 100%<br>(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. |
| **CURVE CUTBACK**<br>(T, TM) | 1% ÷ 100%<br>(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**<br>(T, TM, P) | 0.6 Hz ÷ 25 Hz<br>(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**<br>(T, TM, P, CO) | 0% ÷ 100%<br>(steps of 1/255) | 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**<br>(T, TM, P, CO, MCO) | 1 ÷ 5<br>(steps of 0.1) | This parameter defines the acceleration profile: 1 results in a linear ramp, higher values result in smoother parabolic profiles. |
| **INV SMOOTH**<br>(T, TM, CO, MCO) | 1 ÷ 5<br>(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. |
| **STOP SMOOTH**<br>(T, TM, P, CO, MCO) | 3 Hz ÷ 100 Hz<br>(steps of 1 Hz) | This parameter defines the frequency at which the smoothing effect of the acceleration profile ends. |
| **BRK SMOOTH**<br>(T, TM, CO, MCO) | 1 ÷ 5<br>(steps of 0.1) | This parameter defines the deceleration profile: 1 results in a linear ramp, higher values result in smoother parabolic profiles. |
| **STOP BRK SMOOTH**<br>(T, TM, CO, MCO) | 3 Hz ÷ 100 Hz<br>(steps of 1 Hz) | This parameter defines the frequency at which the smoothing effect of the deceleration profile ends. |

| PARAMETER CHANGE | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **BACKING SPEED**<br>(T, TM) | 10% ÷ 25%<br>(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**<br>(T, TM) | 0 s ÷ 10 s<br>(steps of 0.1 s) | This parameter defines the duration of the inching function. |
| **EB. ENGAGE DELAY**<br>(T, TM, P, CO, G, MCO) | 0 s ÷ 12.75 s<br>(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 datasheet. |
| **AUXILIARY TIME**<br>(T, TM, P, CO, G, MCO) | 0 s ÷ 10 s<br>(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.<br>See parameter STOP ON RAMP (paragraph 8.2.2). |
| **ROLLING DW SPEED**<br>(T, TM, P, CO, G, MCO, TS23) | 1 Hz ÷ 50 Hz<br>(steps of 1 Hz) | This parameter defines the maximum speed for the rolling-down function. |
| **MIN EVP**<br>(A) | 0% ÷ 100%<br>(steps of 1/255) | This parameter determines the minimum current applied to the EVP1 when the potentiometer position is at the minimum. This parameter is not effective if the EVP1 is programmed like an on/off valve or if the EVP1 is disabled. |
| **MAX EVP**<br>(A) | 0% ÷ 100%<br>(steps of 1/255) | This parameter determines the maximum current applied to the EVP1 when the potentiometer position is at the maximum. This parameter also determines the current value when the EVP1 is programmed like an ON/OFF valve. |
| **EVP OPEN DELAY**<br>(A) | 0 s ÷ 12.75 s<br>(steps of 0.05 s) | It determines the current increase rate on EVP1. The parameter sets the time needed to increase the current to the maximum possible value. |
| **EVP CLOSE DELAY**<br>(A) | 0 s ÷ 12.75 s<br>(steps of 0.05 s) | It determines the current decrease rate on EVP1. The parameter sets the time needed to decrease the current from the maximum possible value to zero. |
| **MIN EVP2**<br>(A) | 0% ÷ 100%<br>(steps of 1/255) | This parameter determines the minimum current applied to the EVP2 when the potentiometer position is at the minimum. This parameter is not effective if the EVP2 is programmed like an on/off valve or if the EVP2 is disabled. |
| **MAX EVP2**<br>(A) | 0% ÷ 100%<br>(steps of 1/255) | This parameter determines the maximum current applied to the EVP2 when the potentiometer position is at the maximum. This parameter also determines the current value when the EVP2 is programmed like an ON/OFF valve. |
| **EVP2 OPEN DELAY**<br>(A) | 0 s ÷ 12.75 s<br>(steps of 0.05 s) | It determines the current increase rate on EVP2. The parameter sets the time needed to increase the current to the maximum possible value. |

| PARAMETER CHANGE | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **EVP2 CLOSE DELAY**<br>(A) | 0 s ÷ 12.75 s<br>(steps of 0.05 s) | It determines the current decrease rate on EVP2. The parameter sets the time needed to decrease the current from the maximum possible value to zero. |

## 8.2.2 SET OPTIONS

| SET OPTIONS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **HM DISPLAY OPT.**<br>(T, TM, P) | 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. |
| **HM CUSTOM 1 OPT.**<br>(T, TM, P, CO, G, MCO) | 0 ÷ 6 | This parameter defines the configuration for the hour meter number 1 accessible to the customer.<br>The possible settings are:<br>**0:** The hour meter counts the controller on time (key on).<br>**1:** The hour meter counts the three-phase power bridge active time.<br>**2:** The hour meter counts the DC pump active time. Not used in ACEX NEW GENERATION Foc3.<br>**3:** The hour meter counts the time when at least one of the valve outputs is active.<br>**4:** The hour meter counts the three-phase power bridge active time, or the DC pump active time. In ACEX NEW GENERATION Foc3 it is the same as 1.<br>**5:** The hour meter counts the time when at least one of the valve outputs is active or the DC pump is active. In ACEX NEW GENERATION Foc3 it is the same as 3.<br>**6:** The hour meter counts the time when the three-phase power bridge is active, or at least one of the valve outputs is active, or the DC pump is active. |
| **HM CUSTOM 2 OPT.**<br>(T, TM, P, CO, G, MCO) | 0 ÷ 6 | This parameter defines the configuration for the hour meter number 2 accessible to the customer. The possible settings are the same as HM CUSTOM 1 OPT. parameter. |
| **TILL/SEAT SWITCH**<br>(T, TM, P, G) | List of values | This option handles the input A1 (A11) that is used as operator presence indicator. This input is connected to the key voltage (active) when the operator is present.<br>**DEADMAN =** A1 (A11) is managed as dead-man input (no delay when released).<br>**HANDLE =** A1 (A11) is managed as tiller input (no delay when released).<br>**SEAT =** A1 (A11) is managed as seat input (with a delay when released and with the de-bouncing function). |

| SET OPTIONS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **EB ON TILLER BRK**<br>(T, G) | OFF ÷ ON | This option defines how the electromechanical brake is managed depending on the status of tiller/seat input:<br>**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.<br>**OFF =** when the tiller input goes into OFF state, the “tiller braking” ramp is applied before engaging the electromechanical brake. |
| **BATTERY CHECK**<br>(T, TM, P, CO, G, MCO) | 0 ÷ 3 | This option specifies the management of the low battery charge situation. There are four levels of intervention:<br>**0 =** The battery charge level is evaluated but ignored, meaning that no action is taken when the battery runs out.<br>**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 reduces the maximum current down to 50% of the full current.<br>**2 =** The BATTERY LOW alarm occurs when the battery level is evaluated to be lower or equal to BATT.LOW TRESHLD.<br>**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.<br>See parameter BATT.LOW TRESHLD in the ADJUSTMENTS list. |

| SET OPTIONS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **STOP ON RAMP**<br>(T, TM, P, CO, G, MCO, TS23) | OFF ÷ ON | This parameter enables the stop-on-ramp feature which holds electrically the truck in place on a slope.<br>**ON =** The stop-on-ramp feature is performed at each stop of the truck.<br>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.<br>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.<br>**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.<br>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.<br>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. |
| **PULL IN BRAKING**<br>(A) | OFF ÷ ON | When this parameter is ON, the motor controller applies and holds a certain torque even if the traction (or lift) request has been released.<br>**ON =** In traction applications, when the operator releases the traction request, the inverter keeps running the truck in order to counteract 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.<br>**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 exploiting the gravity, the motor must not be powered anymore, until the truck stops. |

| SET OPTIONS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **SOFT LANDING**<br>(A) | OFF ÷ ON | This parameter enables or disables the control of the deceleration rate of the truck when the accelerator is released.<br>**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. Indeed, if the rise is steep and this function is not active, the truck may stop fast and may also go backwards for a short time, possibly leading to a dangerous situation.<br>**OFF =** When the accelerator is released, the inverter does not control the deceleration rate of the truck, instead it stops driving the motor |
| **QUICK INVERSION**<br>(T, TM, P) | List of values | This parameter defines the quick-inversion functionality.<br>**NONE =** The quick-inversion function is not managed.<br>**BRAKE =** Upon a quick-inversion request, the motor is braked.<br>**TIMED =** The quick-inversion function is timed: upon a quick inversion request, the controller drives the motor in the opposite direction for a fixed time (1.5 seconds by default).<br>**BELLY =** The quick-inversion function is managed but not timed: upon a quick inversion request the controller drives the motor in the opposite direction until the request is released. |
| **PEDAL BRK ANALOG**<br>(T, TM) | OFF ÷ ON | This parameter defines the kind of brake pedal adopted.<br>**ON =** the brake pedal outputs an analog signal and the braking is linear.<br>**OFF =** the brake pedal outputs a digital signal and the braking is on/off. |
| **HARD & SOFT**<br>(T, TM) | OFF ÷ ON | This parameter enables or disables the Hard-and-Soft functionality. When H&S is enabled, it is possible to start the truck at reduced speed only activating the H&S switch and the accelerator, without the TILLER input.<br>**OFF =** H&S function is disabled (default option).<br>**ON =** H&S function is enabled. |
| **HB ON / SR OFF**<br>(T, TM) | OFF, ON | This parameter enables or disables the handbrake/speed reduction function linked to the pin A18 (A12) when used as cutback1:<br>**ON =** Handbrake.<br>**OFF =** Speed reduction. |

| SET OPTIONS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **MAIN POT. TYPE**<br>(T, TM, P) | 0 ÷ 11 | This parameter defines the feature of the main potentiometer, connected to pin A15 (A9). |

| # | Pot. type | Low to High / High to Low | Direction switches | Enable switch | En. dead band |
|---|---|---|---|---|---|
| **0** | V-type | L to H | X | | |
| **1** | V-type | L to H | X | | X |
| **2** | V-type | H to L | X | | |
| **3** | V-type | H to L | X | | X |
| **4** | Z-type | L to H | X | | |
| **5** | Z-type | L to H | X | | X |
| **6** | Z-type | L to H | | X | X |
| **7** | Z-type | L to H | | | X |
| **8** | Z-type | H to L | X | | |
| **9** | Z-type | H to L | X | | X |
| **10** | Z-type | H to L | | X | X |
| **11** | Z-type | H to L | | | X |
| **12** | V-type* | L to H | | | X |
| **13** | No** | H to L | | X | |
| **14** | V-type | L to H | X | X | |

*V-type potentiometer without direction switches: the motor spins always in the same direction.

**In pump configuration, only the enable (lift) switch is used, without potentiometer analog input. When the lift is active, the controller drives the pump motor at the maximum speed. In traction configuration the option 13 is the same as 12.

See paragraph 9.4 for a more detailed description about the potentiometer types.

| SET OPTIONS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **AUX POT. TYPE**<br>(T, TM, P) | 0 ÷ 12 | This parameter decides the type of the auxiliary potentiometer, connected to pin A30 (A20). |

| # | Pot. type | Low to High / High to Low | Direction switches | Enable switch | En. dead band |
|---|---|---|---|---|---|
| **0 ÷ 11** | Same as MAIN POT. TYPE. See previous parameter. | | | | |
| **12** | No* | H to L | X | X | |
| **13** | Crossed twin together with the main potentiometer. | | | | |
| **14** | Same as **0** | | | | |
| **15** | Not used, reserved for future development | | | | |

*The potentiometer analog input is not used; only direction switches and enable.

| Parameter | Allowable range | Description |
|---|---|---|
| **SET MOT.TEMPERAT**<br>(T, TM, P, CO, G, MCO, TS23) | List of values | This parameter defines the type of motor temperature sensor connected to A22 (A13).<br>**NONE =** None.<br>**DIGITAL =** Digital (ON/OFF) motor thermal sensor.<br>**KTY-84 =** KTY 84-130.<br>**KTY-83 =** KTY 83-130.<br>**PT-1000 =** PT1000 PTC.<br>**KTY-81 =** KTY81-110/120. |

| SET OPTIONS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **STEERING TYPE**<br>(T, TM, MCO) | List of values | This parameter defines which type of steering unit is connected to the controller via CAN bus.<br>**NONE =** No steering module is present on the truck. ACEX NEW GEN does not wait for CAN messages from the EPS and it does not apply EPS and braking steer cutback.<br>**ANALOG =** A hydraulic steering system is used on the truck and the ACEX NEW GEN reads through one of its analog input the signal coming from a wheel potentiometer in order to read the wheel rotation.<br>**C.O. =** If the parameter PDO2RX is enabled and the CONTROLLER TYPE is set to C.O., then the ACEX NEW GEN receives the speed and the steering angle information in PDO2 via a CAN command.<br>**OPTION#1 =** EPS Minifit is present and it is configured with an ENCODER + TOGGLE SWITCHES. These signals are transmitted to ACEX NEW GEN over CAN bus.<br>**OPTION#2 =** EPS Minifit is present in the POT + ENCODER configuration. These signals are transmitted to ACEX NEW GEN over CAN bus.<br>**OPTION#3** = EPS AC0 Ampseal is present in the ENCODER + TOGGLE SWITCHES configuration. These signals are transmitted to ACEX NEW GEN over CAN bus. |
| **STEERING POT POS**<br>(TM, MCO) | 0 ÷ 3 | This parameter defines which controller reads the steering potentiometer. It is available in the master unit of a multi-motor application and it is used when STEERING TYPE = ANALOG.<br>**0** = Master controller, on pin A30 (A20).<br>**1 ÷ 3** = Slave controller 1 ÷ 3, on pin A15 (A9). |
| **M.C. FUNCTION**<br>(A) | List of values | This parameter defines the configuration of the NLC output A12 (A16), dedicated to the main – or line – contactor.<br>**OFF =** The main contactor is not present and its diagnoses are masked. The MC is not driven.<br>**ON =** The main contactor is present and ACEX NEW GEN is in standalone configuration. The diagnoses are performed and the MC is closed after key-on only in no alarms conditions.<br>**OPTION#1 =** in a traction controller plus a pump controller configuration, with only one main contactor for both the controllers. The diagnoses are performed and the MC is closed after key-on only in no alarms conditions.<br>**OPTION#2 =** in a traction controller plus a pump controller configuration, with two main contactors. Each controller drives its own MC. The diagnoses are performed and MCs are closed after key-on only in no alarms conditions. |

| SET OPTIONS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **M.C. OUTPUT**<br>(A) | ABSENT, PRESENT | This parameter defines whether a load coil is connected to the NLC output A12 (A16) or not.<br>**ABSENT =** NLC output is not connected to any load coil.<br>**PRESENT =** NLC output is connected to a load coil (by default, that of the main contactor). |
| **EBRAKE ON APPL.**<br>(T, TM, P, CO, G, MCO, TS23) | ABSENT, PRESENT | This parameter defines whether the application includes an electromechanical brake or not. |
| **AUX OUT FUNCTION**<br>(A) | NONE, BRAKE | This parameter enables or disables the NEB output A4 (A2), dedicated to the electromechanical brake.<br>**NONE =** the diagnoses are masked and the output A4 (A2) is not driven upon a traction request.<br>**BRAKE =** E.B. is driven upon a traction request if all the related diagnoses do not fail. The behavior on a slope depends on the STOP ON RAMP setting. Do not use the STOP ON RAMP setting if the electromechanical brake is not present.<br>**Note:** 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**<br>(A) | 0 ÷ 3 | This parameter defines the voltage compensation for the MC and EB drivers in dependence of the battery voltage.<br>**0 =** None.<br>**1 =** MC only.<br>**2 =** EB only.<br>**3 =** MC and EB. |
| **EMERCENCY INPUT**<br>(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 A31 (A21).<br>**0 =** Emergency function is disabled.<br>**1 =** Emergency function is enabled and an alarm is raised in case of an emergency event.<br>**2 =** Emergency function is enabled, without any linked alarm. |
| **SYNCRO**<br>(CO, MCO, SCO, G) | OFF ÷ ON | This parameter enables or disables the syncro message.<br>**OFF =** The syncro message is not used<br>**ON =** The syncro message is enabled |
| **AUTO PARK BRAKE**<br>(CO, MCO, SCO, G) | OFF ÷ ON | It enables or disables the autonomous management of the brake output:<br>**OFF =** the output is activated or deactivated according to the signal received via CAN bus.<br>**ON =** the output is managed autonomously by the controller itself ignoring any activation/deactivation signal received via CAN bus. |

| SET OPTIONS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **ACCEL MODULATION**<br>(T, TM, P, CO, G, MCO) | List of values | This parameter enables or disables the acceleration-modulation function. See paragraph 9.5.<br>**OFF =** The acceleration rate is inversely proportional to the ACCELER. DELAY parameter.<br>**ON =** The acceleration ramp is inversely proportional to the ACCELER. DELAY parameter only if speed setpoint is greater than 100 Hz. Below 100 Hz the acceleration ramp is also proportional to the speed setpoint, so that the acceleration duration results equal to ACCELER. DELAY.<br>**OPTION #1 =** reserved for future developments. |
| **EVP TYPE**<br>(A) | List of values | This parameter defines the behavior of output EVP A24 (A1).<br>**NONE =** Output A24 (A1) is not enabled.<br>**DIGITAL =** Output A24 (A1) manages an on/off valve. By default, it is activated by input LOWER A20 (A14).<br>**ANALOG =** Output A24 (A1) manages a PWM-modulated current-controlled proportional valve. By default, it is activated by input LOWER A20 (A14) and the current setpoint is read on the analog input CPOT2 A30 (A20). |
| **EVP2 TYPE**<br>(A) | List of values | This parameter defines the behavior of output EVP2 A23.<br>**NONE =** Output A23 is not enabled.<br>**DIGITAL =** Output A23 manages an on/off valve. By default, it is activated by input LOWER A20 (A14).<br>**ANALOG =** Output A23 manages a PWM-modulated current-controlled proportional valve. |
| **EV1**<br>(A) | List of values | This parameter defines the behavior of output EV1 A9 (A7).<br>**ABSENT =** Output A9 is not enabled.<br>**OPTION#1 =** Output A9 manages a PWM voltage-controlled valve. The PWM frequency is 1 kHz and the duty cycle depends on parameter PWM EV1 (ADJUSTMENTS submenu 8.2.3). By default it is activated by the 1st speed command A17.<br>**OPTION#2 =** output A9 manages an external pre-charge path.<br>**OPTION#3 =** output A9 manages an external horn. It is activated by the horn input.<br>**OPTION#4 =** output A9 is used as alarm code. |
| **EV2**<br>(A) | ABSENT ÷ DIGITAL | This parameter defines the behavior of output EV2 A11.<br>**ABSENT =** Output A11 is not enabled.<br>**DIGITAL =** Output A11 manages a PWM voltage-controlled valve. The PWM frequency is 1 kHz and the duty cycle depends on parameter PWM EV2 (ADJUSTMENTS submenu 8.2.3). By default it is activated by the 2nd speed command A16. |

| SET OPTIONS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **EV3**<br>(A) | ABSENT ÷ DIGITAL | This parameter defines the behavior of output EV3 A33 (A23).<br>**ABSENT =** Output A33 (A23) is not enabled.<br>**DIGITAL =** Output A33 (A23) manages a PWM voltage-controlled valve. The PWM frequency is 1 kHz and the duty cycle depends on parameter PWM EV3 (ADJUSTMENTS submenu 8.2.3). By default it is activated by the lift command. |
| **EV4**<br>(A) | ABSENT ÷ DIGITAL | This parameter defines the behavior of output EV4 A34.<br>**ABSENT =** Output A34 is not enabled.<br>**DIGITAL =** Output A34 manages a PWM voltage-controlled valve. The PWM frequency is 1 kHz and the duty cycle depends on parameter PWM EV4 (ADJUSTMENTS submenu 8.2.3). By default it is activated by the backward command. |
| **EV5**<br>(A) | ABSENT ÷ DIGITAL | This parameter defines the behavior of output EV5 A8 (A6).<br>**ABSENT =** Output A8 (A6) is not enabled.<br>**DIGITAL =** Output A8 (A6) manages a PWM voltage-controlled valve. The PWM frequency is 1 kHz and the duty cycle depends on parameter PWM EV5 (ADJUSTMENTS submenu 8.2.3). |
| **EV6**<br>(A) | ABSENT ÷ DIGITAL | This parameter defines the behavior of output EV6 A26.<br>**ABSENT =** Output A26 is not enabled.<br>**DIGITAL =** Output A26 manages a PWM voltage-controlled valve. The PWM frequency is 1 kHz and the duty cycle depends on parameter PWM EV6 (ADJUSTMENTS submenu 8.2.3). By default it is activated by the horn command. |
| **HIGH DYNAMIC**<br>(T, TM, P, CO, G, MCO) | OFF ÷ ON | This parameter enables or disables the high-dynamic function.<br>**ON =** All acceleration and deceleration profiles set by dedicated parameters are ignored. The controller works always with maximum performance.<br>**OFF =** Standard behavior. |
| **INVERSION MODE**<br>(T, TM) | OFF ÷ ON | This parameter sets the behavior of the Quick-Inversion input A7 (A5):<br>**ON =** The Quick-Inversion switch is normally closed (function is active when the switch is open).<br>**OFF =** The Quick-Inversion switch is normally open (function is active when the switch is closed). |

| SET OPTIONS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **STEER TABLE**<br>(TM, MCO) | List of values | This parameter defines the steering table.<br>**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.<br>**OPTION#1 =** Three-wheels predefined steering table.<br>**OPTION#2 =** Four-wheels predefined steering table.<br>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.<br>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**<br>(TM, MCO) | 0 ÷ 32000 | This parameter must be filled with the wheelbase distance, i.e. the distance present between the two truck axles. The distance must be expressed in millimeters.<br>See paragraph 9.16. |
| **FIXED AXLE MM**<br>(TM, MCO) | 0 ÷ 32000 | This parameter must be filled with the axle length to which the non-steering wheels are connected (center to center distance). The length must be expressed in millimeters.<br>See paragraph 9.16. |
| **STEERING AXLE MM**<br>(TM, MCO) | 0 ÷ 32000 | For four-wheel trucks, this parameter must be filled with the axle length to which the steering wheels are connected, between the two pivot points. The length must be expressed in millimeters.<br>For three-wheel trucks, it is to be set equal to zero.<br>See paragraph 9.16. |
| **REAR POT ON LEFT**<br>(TM, MCO) | OFF ÷ ON | This parameter defines the position of the steering potentiometer.<br>**OFF =** The steering potentiometer is not placed on the rear-left wheel.<br>**ON =** The steering potentiometer is placed on the rear-left wheel. |
| **DISPLAY TYPE**<br>(T, TM, P) | 0 ÷ 9 | This parameter defines which type of display is connected to the inverter.<br>**0 =** None.<br>**1 =** MDI PRC.<br>**2 =** ECO DISPLAY.<br>**3 =** SMART DISPLAY.<br>**4 =** MDI CAN.<br>**5 ÷ 9 =** free for future developments. |

| SET OPTIONS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **PDO2RX**<br>(CO, MCO, G) | ABSENT ÷ PRESENT | This parameter defines whether the message PDO2RX is expected to be received.<br>**ABSENT =** Message PDO2RX is not expected to be received.<br>**PRESENT =** Message PDO2RX is expected to be received. If it is not received, a CAN alarm is raised. |
| **PDO3TX**<br>(CO, MCO, G) | 0 ÷ 9 | This parameter defines whether the controller sends the message PDO3TX on the CAN network.<br>**0 =** Message PDO3TX is not sent.<br>**1 ÷ 9** = Message PDO3TX is sent on the CAN network. |
| **PERFORMANCE**<br>(T, TM, P) | OFF ÷ ON | This parameter enables the selection of the performance mode.<br>**OFF =** normal performance level selected and locked.<br>**ON =** the user can change the performance level from normal to economy or power. |
| **BMS FUNCTION**<br>(T, TM, P, CO, G, MCO) | OFF ÷ ON | This parameter defines the battery monitoring strategy.<br>**OFF =** The controller monitors the battery voltage and the battery state of charge.<br>ON = The controller receives information about the battery state of charge from the BMS. |
| **BRK TORQUE BMS**<br>(T, TM, P, CO, G, MCO) | OFF ÷ ON | This parameter enables the torque profile limitation<br>**OFF =** torque profile limitation disabled.<br>**ON =** the controller enables the torque profile limitation based on the battery state of charge information transmitted by the BMS. It takes effect only if the BMS FUNCTION parameter is set to ON. |
| **STO**<br>(CO) | OFF ÷ ON | This parameter enables the Safe Torque Off (STO) function featured by the CAN operated versions of the controller. If ON, a stop category 0 is implemented, in accordance with IEC 60204-1:<br>• Uncontrolled stopping by means of immediate interruption of the supply of power to the actuators.<br>• Safe restart interlock: prevents unexpected starting of the motor. |

| SET OPTIONS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **SS1**<br>(CO) | 0 ÷ 2 | This parameter defines the Safe Stop 1 (SS1) function featured by the CAN operated versions of the controller. SS1 function corresponds to stop category 1 in accordance with IEC 60204-1:<br>• Controlled stopping while maintaining the supply of power to the actuators.<br>• After stopping or below a predefined speed limit the STO function is activated.<br>• Optional monitoring of a brake ramp.<br>**0 =** SS1 function is not active.<br>**1 =** Monitored: the braking ramp is monitored and if the deceleration ramp performed does not match the braking ramp defined by SS1 BRAKING parameter then the inverter rises an alarm and applies STO.<br>**2 =** Time-dependent: the braking ramp and the total braking time are monitored. If the deceleration ramp performed does not match the braking ramp defined by SS1 BRAKING parameter and/or the total braking time defined by GSS1 BRK. TIME parameter then the inverter rises an alarm, applies STO and activates the electromechanical brake. |

### 8.2.3 ADJUSTMENTS

| ADJUSTMENTS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **SET BATTERY**<br>(A) | List of values | This parameter must be set to the nominal battery voltage. The available options are:<br>**24V**, **36V**, **48V**, **72V**, **80V** |
| **ADJUST KEY VOLT.**<br>(A) | | Fine adjustment of the key voltage measured by the controller. Calibrated by Zapi production department during the end of line test. |
| **ADJUST BATTERY**<br>(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**<br>(A) | List of values | This parameter defines the voltage on pin PEB A2 (A19). Available values are:<br>**12V**, **24V**, **36V**, **40V**, **48V**, **72V**, **80V, 96V** |
| **SET PBRK. MIN**<br>(T, TM) | 0 V ÷ 25.5 V<br>(steps of 0.1 V) | It records the minimum value of the brake potentiometer when the brake is set to analog. |
| **SET PBRK. MAX**<br>(T, TM) | 0 V ÷ 25.5 V<br>(steps of 0.1V) | It records the maximum value of the brake potentiometer when the brake is set to analog. |
| **MIN LOWER**<br>(T, TM, TS1, P) | 0 V ÷ 25.5 V<br>(steps of 0.1V) | It records the minimum value of the lower potentiometer A30 (A20) when the lower switch is closed.<br>See paragraph 9.2. |

| ADJUSTMENTS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **MAX LOWER**<br>(T, TM, TS1, P) | 0 V ÷ 25.5 V<br>(steps of 0.1V) | It records the maximum value of the lower potentiometer A30 (A20) when the lower switch is closed.<br>See paragraph 9.2. |
| **THROTTLE 0 ZONE**<br>(T, TM, P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines a dead band in the accelerator input curve.<br>See paragraph 9.10. |
| **THROTTLE X1 MAP**<br>(T, TM, P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the accelerator input curve.<br>See paragraph 9.10. |
| **THROTTLE Y1 MAP**<br>(T, TM, P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the accelerator input curve.<br>See paragraph 9.10. |
| **THROTTLE X2 MAP**<br>(T, TM, P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the accelerator input curve.<br>See paragraph 9.10. |
| **THROTTLE Y2 MAP**<br>(T, TM, P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the accelerator input curve.<br>See paragraph 9.10. |
| **THROTTLE X3 MAP**<br>(T, TM, P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the accelerator input curve.<br>See paragraph 9.10. |
| **THROTTLE Y3 MAP**<br>(T, TM, P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the accelerator input curve.<br>See paragraph 9.10. |
| **BAT. MIN ADJ.**<br>(T, TM, P, CO, G, MCO) | -12.8% ÷ 12.7%<br>(steps of 0.1%) | It adjusts the lower level of the battery discharge table. It is used to calibrate the discharge algorithm for the battery used.<br>See paragraph 9.12. |
| **BAT. MAX ADJ.**<br>(T, TM, P, CO, G, MCO) | -12.8% ÷ 12.7%<br>(steps of 0.1%) | It adjusts the upper level of the battery discharge table. It is used to calibrate the discharge algorithm for the battery used.<br>See paragraph 9.12. |
| **BDI ADJ STARTUP**<br>(T, TM, P, CO, G, MCO) | -12.8% ÷ 12.7%<br>(steps of 0.1%) | It adjusts the upper and lower levels of the battery charge table at start-up, in order to calculate and update the battery charge information at key-on.<br>See paragraph 9.12. |
| **BDI RESET**<br>(T, TM, P, CO, G, MCO) | 0% ÷ 100%<br>(steps of 1%) | It adjusts the minimum variation of the battery discharge table to update the battery charge information at start up. It is used to calibrate the discharge algorithm for the battery used.<br>See paragraph 9.12. |
| **BATT.LOW TRESHLD**<br>(T, TM, P, CO, G, MCO) | 1% ÷ 50%<br>(steps of 1%) | This parameter defines the minimum charge percentage below which the BATTERY LOW alarm rises. |

| ADJUSTMENTS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **BAT.ENERGY SAVER**<br>(T, TM, P, CO, G, MCO, TS23) | 0% - 100%<br>(256 steps) | This parameter defines the percentage of the maximum output torque delivered when the battery charge reaches the 10%. Indeed, if the BAT.ENERGY SAVER parameter is set less than 100% then a linear reduction of the torque profile is performed as described in paragraph 9.13.<br>If the battery-saving feature is not desired, BAT.ENERGY SAVER should be set equal to 100%. |
| **VOLTAGE THR LOW**<br>(A) | 0% ÷ 255%<br>(steps of 1%) | This parameter defines the voltage low threshold for the working voltage range, expressed as percentage 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. See paragraph 2.4 for more details. The default value is 80%.<br>In case the check fails, alarms WRONG KEY VOLT. or WRONG SET BAT. are raised. See paragraph 10.1. |
| **VOLTAGE THR HIGH**<br>(A) | 0% ÷ 255%<br>(steps of 1%) | This parameter defines the voltage high threshold for the working voltage range, expressed as percentage 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. See paragraph 2.4 for more details. The default value is 120%.<br>In case the check fails, alarms WRONG KEY VOLT. or WRONG SET BAT. are raised. See paragraph 10.1. |
| **STEER RIGHT VOLT**<br>(T,TM, MCO) | 0 V ÷ 25.5 V<br>(steps of 0.1 V) | This parameter records the maximum steering-control voltage while turning right.<br>See paragraph 9.3. |
| **STEER LEFT VOLT**<br>(T,TM, MCO) | 0 V ÷ 25.5 V<br>(steps of 0.1 V) | This parameter records the maximum steering-control voltage while turning left.<br>See paragraph 9.3. |
| **STEER ZERO VOLT**<br>(T,TM, MCO) | 0 V ÷ 25.5 V<br>(steps of 0.1 V) | This parameter records the steering-control voltage when it is in the straight-ahead position.<br>See paragraph 9.3. |
| **MAX ANGLE RIGHT**<br>(T,TM, MCO) | 0° ÷ 90°<br>(steps of 1°) | This parameter defines the maximum steering-wheel angle while turning right. |
| **MAX ANGLE LEFT**<br>(T,TM, MCO) | 0° ÷ 90°<br>(steps of 1°) | This parameter defines the maximum steering-wheel angle while turning left. |
| **STEER DEAD ANGLE**<br>(T, TM) | 1° ÷ 50°<br>(steps of 1°) | This parameter defines the maximum steering-wheel angle up to which the permitted traction speed is 100%.<br>See paragraph 9.9. |

| ADJUSTMENTS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **STEER ANGLE 1**<br>(T, TM) | 1° ÷ 90°<br>(steps of 1°) | This parameter defines the steering-wheel angle at which traction speed is reduced to the value imposed by CURVE SPEED 1.<br>For steering-wheel angles between STEER DEAD ANGLE and STEER ANGLE 1, traction speed is reduced linearly from 100% to CURVE SPEED 1.<br>See paragraph 9.9. |
| **STEER ANGLE 2**<br>(T, TM) | 1° ÷ 90°<br>(steps of 1°) | This parameter defines the steering-wheel angle beyond which traction speed is reduced to CURVE CUTBACK.<br>For steering-wheel angles between STEER ANGLE1 and STEER ANGLE 2 traction speed is reduced linearly from CURVE SPEED 1 to CURVE CUTBACK.<br>See paragraph 9.9. |
| **SPEED FACTOR**<br>(T, TM, CO, MCO) | 0 ÷ 255<br>(steps of 1) | 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<br>$Speed\ [km/h] = 10 \cdot \frac{frequency\ [Hz]}{Speed\ factor}$<br>The speed factor can be calculated using the following formula:<br>$Speed\ factor = \frac{88 \cdot rr \cdot pp}{\emptyset}$<br>$rr$: total gearbox reduction ratio.<br>$pp$: motor poles pair.<br>$\emptyset$: traction wheel diameter expressed in cm. |
| **SPEED ON MDI**<br>(T, TM, P) | OFF ÷ ON | This parameter enables or disables the speed visualization on the MDI display:<br>**ON =** MDI shows traction speed when the truck is moving. In steady-state condition the speed indication is replaced by the hour-meter indication.<br>**OFF =** Standard MDI functionality. |
| **LOAD HM FROM MDI**<br>(T, TM, P) | 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 any MDI CAN is not present on the machine, this parameter has not effect.<br>**OFF =** The controller hour-meter increases over time normally.<br>**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**<br>(T, TM, P, CO, G, MCO) | OFF ÷ ON | In order to cancel the CHECK UP NEEDED warning, set this parameter ON after the required maintenance service. |

| ADJUSTMENTS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **CHECK UP TYPE**<br>(T, TM, P, CO, G, MCO) | List of values | This parameter defines the CHECK UP NEEDED warning:<br>**NONE =** no CHECK UP NEEDED warning.<br>**OPTION#1 =** CHECK UP NEEDED warning shown on the hand-set and MDI after 300 hours.<br>**OPTION#2 =** Like OPTION#1, plus speed reduction intervenes after 340 hours.<br>**OPTION#3 =** Like OPTION#2, plus the truck definitively stops after 380 hours. |
| **MC VOLTAGE**<br>(A) | 0% ÷ 100%<br>(steps of 1%) | This parameter specifies the duty-cycle of the PWM applied to the main-contactor output A12 (A16) during the first second after the activation signal that causes the main contactor to close. |
| **MC VOLTAGE RED.**<br>(A) | 0% ÷ 100%<br>(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.<br>For details and examples see paragraph 9.11 |
| **EB VOLTAGE**<br>(A) | 0% ÷ 100%<br>(steps of 1%) | This parameter specifies the duty-cycle of the PWM applied to the electromechanical brake output A4 (A2) during the first second after the activation signal that causes the electromechanical brake to release. |
| **EB VOLTAGE RED.**<br>(A) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines a percentage of EB VOLTAGE parameter and it determines the duty-cycle applied after the first second since the electromechanical brake has been released.<br>For details and examples see paragraph 9.11. |
| **PWM EV1**<br>(A) | 0% ÷ 100%<br>(255 steps) | This parameter defines the on-state duty-cycle of the PWM applied to EV1 output A9 (A7) when the output is active. |
| **PWM EV2**<br>(A) | 0% ÷ 100%<br>(255 steps) | This parameter defines the on-state duty-cycle of the PWM applied to EV2 output A11 when the output is active. |
| **PWM EV3**<br>(A) | 0% ÷ 100%<br>(255 steps) | This parameter defines the on-state duty-cycle of the PWM applied to EV3 output A33 (A23) when the output is active. |
| **PWM EV4**<br>(A) | 0% ÷ 100%<br>(255 steps) | This parameter defines the on-state duty-cycle of the PWM applied to EV4 output A34 when the output is active. |
| **PWM EV5**<br>(A) | 0% ÷ 100%<br>(255 steps) | This parameter defines the on-state duty-cycle of the PWM applied to EV5 output A8 (A6) when the output is active. |
| **PWM EV6**<br>(A) | 0% ÷ 100%<br>(255 steps) | This parameter defines the on-state duty-cycle of the PWM applied to EV6 output A26 when the output is active. |
| **MAX. MOTOR TEMP.**<br>(T, TM, P, CO, G, MCO, TS23) | 0°C ÷ 255°C<br>(steps of 1°C) | This parameter defines the motor temperature above which a linear 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 independently by the temperature. See paragraph 9.17. |

| ADJUSTMENTS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **STOP MOTOR TEMP.**<br>(T, TM, P, CO, G, MCO, TS23) | 0°C ÷ 255°C<br>(steps of 1°C) | This parameter defines the maximum motor temperature permitted above which the maximum motoring current is limited to the percentage set in the parameter MOT.T. T.CUTBACK. |
| **MOT.T. T.CUTBACK**<br>(T, TM, P, CO, G, MCO, TS23) | 0% - 100%<br>(256 steps) | This parameter defines the motor thermal cutback. The control linearly reduces the motor current basing on the motor temperature. Reference limits of the linear reduction are MAX MOTOR TEMP and TEMP. MOT. STOP.<br>See paragraph 9.17. |
| **VACC SETTING**<br>(T, TM, P,TS1) | | The Acquire button enables the acquisition of the accelerator potentiometer.<br>See paragraph 9.1 |
| **IDC BUS SENSOR**<br>(G) | OFF, ON | This parameter defines whether an external sensor for the battery current is present on the CAN bus network.<br>**ON =** The controller reads the DC current measure by an external sensor via the CAN bus network.<br>**OFF =** No external current sensor is present, software estimates the DC current upon the AC power, considering estimated internal losses as well. |

### 8.2.4 SPECIAL ADJUSTMENTS

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

| SPECIAL ADJUSTMENTS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **ADJUSTMENT #01**<br>**(Read Only)**<br>(A) | Reserved | Gain of the first traction-motor current-sensing amplifier.<br>NOTE: only Zapi technicians can change this value through a special procedure. |
| **ADJUSTMENT #02**<br>**(Read Only)**<br>(A) | Reserved | Gain of the second traction-motor current-sensing amplifier.<br>NOTE: only Zapi technicians can change this value through a special procedure. |
| **CURR. SENS. COMP**<br>(A) | OFF ÷ ON | This parameter enables or disables the linear compensation for the current sensors.<br>NOTE: only Zapi technicians can change this value through a special procedure. |

| SPECIAL ADJUSTMENTS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **CURR. FALLBACK**<br>(A) | OFF ÷ ON | This parameter enables the current reduction after one minute of traction.<br>**ON =** Current reduction is enabled.<br>**OFF =** Current reduction is disabled. |
| **SET CURRENT**<br>**(Read Only)**<br>(A) | List of values | (Factory adjusted). This is the maximum current that the inverter can provide to the motor.<br>See paragraph 2.3 current ratings.<br>NOTE: only Zapi technicians can change this value. |
| **SET TEMPERATURE**<br>(A) | -77°C ÷ 127°C<br>(steps of 1°C) | This parameter calibrates the controller-temperature reading. |
| **HW BATTERY RANGE**<br>(A) | 0 ÷ 2<br>(steps of 1) | This parameter defines the battery voltage range.<br>NOTE: only Zapi technicians can change this value.<br>**0 =** 24 V<br>**1 =** 36 V 48 V<br>2 = 72 V 80 V |
| **HW EXTENSION**<br>**(Read Only)**<br>(A) | PREMIUM<br>STANDARD | This parameter specifies the connector type:<br>**PREMIUM**: the inverter is equipped with a 35-poles Ampseal connector.<br>**STANDARD**: the inverter is equipped with a 23-poles Ampseal connector and a restricted features subset.<br>NOTE: only Zapi technicians can change this value. |
| **PWM AT LOW FREQ**<br>(A) | Reserved | This parameter defines the power-bridge PWM frequency at low speed.<br>NOTE: only Zapi technicians can change this value through a special procedure. |
| **PWM AT HIGH FREQ**<br>(A) | Reserved | This parameter defines the power-bridge PWM frequency at high speed.<br>NOTE: only Zapi technicians can change this value through a special procedure. |
| **FREQ TO SWITCH**<br>(A) | 5 Hz ÷ 255 Hz<br>(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.<br>NOTE: only Zapi technicians can change this value through a special procedure. |
| **DITHER AMPLITUDE**<br>(A) | 0% ÷ 13.3% | 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 a set-point variation is optimized. This parameter is a percentage of the valve maximum current. Setting the parameter to 0% means the dither is not used.<br>The available values are:<br>**0.0%, 0.8%, 2.4%, 3.9%, 5.5%, 7.1%, 8.6%, 10.2%, 11.8%, 13.3%** |

| SPECIAL ADJUSTMENTS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **DITHER FREQUENCY**<br>(A) | 20.8 Hz ÷ 83.3 Hz | This parameter defines the dither frequency.<br>The available values are:<br>**20.8, 22.7, 25, 27.7, 31.2, 35.7, 41.6, 50, 62.5, 83.3** |
| **CAN BUS SPEED**<br>(A) | 20 kbps ÷ 1000 kbps | This parameter defines the CAN bus data-rate in kbps.<br>**20, 50, 125, 250, 500, 800, 1000** |
| **DEBUG CANMESSAGE**<br>(A) | 0 ÷ 15 | This parameter enables or disables special debug messages. Contact a Zapi technician in order to enable and log the correct debug messages. |
| **SAFETY DEBUG**<br>(A) | OFF, ON | This parameter enables or disables special debug messages about the STO and SS1 functions. |
| **CONTROLLER TYPE**<br>(A) | List of values | This parameter defines the controller type:<br>**STANDARD TRACT. =** Standalone traction controller<br>**STANDARD PUMP =** Pump controller<br>**C.O. =** CAN operated<br>**MASTER T =** Multi-motor traction (master)<br>**SLAVE1 T =** Multi-motor traction (slave 1)<br>**SLAVE2 T =** Multi-motor traction (slave 2)<br>**SLAVE3 T =** Multi-motor traction (slave 3)<br>**GENSET =** Hybrid generation set<br>**MASTER C =** CAN-operated, multi-motor traction (master)<br>**SLAVE1 C =** CAN-operated, multi-motor traction (slave 1)<br>**NOTE:** a mismatch between this parameter and the hardware configuration may lead to a severe malfunctioning of the controller. |
| **MOTOR TYPE**<br>(A) | List of values | This parameter defines the technology of the controlled motor.<br>**AC MOTOR =** Asynchronous motors (ACIM).<br>**BL MOTOR =** Brushless synchronous motors (PMSM, IPMSM, BLDC).<br>**SRPM MOT =** Synchronous reluctance permanent-magnet motors (SRPM).<br>**NOTE:** a mismatch between this parameter and the motor in use may lead to a severe malfunctioning of the controller. |
| **CONTROLLER SLV1**<br>(TM, MCO) | List of values | In multi-motor configurations, this parameter defines if the traction slave 1 controller is present.<br>**ABSENT =** the traction slave 1 unit is not present.<br>**PRESENT =** the traction slave 1 unit is present under the same main contactor controlled by the master unit.<br>**OPTION #1 =** the traction slave 1 unit is present under its own main contactor. |

| SPECIAL ADJUSTMENTS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **CONTROLLER SLV2**<br>(TM, MCO) | List of values | In multi-motor configurations, this parameter defines if the traction slave 2 controller is present.<br>**ABSENT =** the traction slave 2 unit is not present.<br>**PRESENT =** the traction slave 2 unit is present under the same main contactor controlled by the master unit.<br>**OPTION #1 =** the traction slave 2 unit is present under its own main contactor. |
| **CONTROLLER SLV3**<br>(TM, MCO) | List of values | In multi-motor configurations, this parameter defines if the traction slave 3 controller is present.<br>**ABSENT =** the traction slave 3 unit is not present.<br>**PRESENT =** the traction slave 3 unit is present under the same main contactor controlled by the master unit.<br>**OPTION #1 =** the traction slave 3 unit is present under its own main contactor. |
| **CONFIG. SLAVES**<br>(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).<br>**0 =** The second and, possibly, third slave units mirror the same speed and torque set-point of the master one.<br>**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.<br>See parameter CONTROLLER TYPE. |
| **AGV**<br>(T) | OFF ÷ ON | This parameter enables the automatic guide.<br>**OFF =** The automatic guide is disabled. The controller gets the speed reference from the dedicated analog input.<br>**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 via CAN messages. In case the periodic automatic-guide-request message is missed, then the controller raises an alarm and the traction is stopped. |

| SPECIAL ADJUSTMENTS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **SAFETY LEVEL**<br>(T, TM, P, CO, G, TS23, MCO) | 0 ÷ 4 | This parameter defines the safety level of the controller, i.e. the functionality of the supervisor microcontroller.<br>**0 =** Supervisor MCU does not check any signal.<br>**1 =** Supervisor MCU checks the inputs and the outputs.<br>**2 =** Supervisor MCU checks the inputs and the motor set-point.<br>**3 =** Supervisor MCU checks the inputs, the outputs and the motor set-point.<br>**4 =** Like level 3, plus safety functions as per regulation EN1175. |
| **RS232 CONSOLLE**<br>(A) | OFF ÷ ON | This parameter enables or disables the possibility to change settings using the smart console.<br>NOTE: only Zapi technicians can change this value. |
| **NODE ID**<br>(A) | 0 ÷ 126<br>(steps of 1) | This parameter defines the ID number of the master unit of the inverter over the CAN bus.<br>**0 =** the default identification number is assigned to the master node.<br>**1 ÷ 126** = this value will be the new node identification number of the master MCU.<br>The supervisor ID is always the master ID + 1. |
| **2ND SDO ID OFST**<br>(A) | 0 ÷ 126<br>(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**<br>(T, TM, P, CO, G, MCO, TS23) | 0% ÷ 255%<br>(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. |
| **VDC UP LIMIT**<br>(T, TM, P, CO, G, MCO, TS23) | 0% ÷ 255%<br>(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. |
| **VDC START DW LIM**<br>(T, TM, P, CO, G, MCO, TS23) | 0% ÷ 255%<br>(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). |
| **VDC DW LIMIT**<br>(T, TM, P, CO, G, MCO, TS23) | 0% ÷ 255%<br>(steps of 1%) | This parameter defines the battery voltage (as percentage of nominal voltage) below which the inverter stops the power section in order to avoid an uncontrolled shutdown due to an under-voltage condition. |

### 8.2.5 HARDWARE SETTING

The HARDWARE SETTING group includes the motor-control-related parameters.

*Hereby, only those parameters that the user is allowed to modify are described. For descriptions and teaching about missing parameters contact a Zapi technician.*

| HARDWARE SETTING | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **TOP MAX SPEED**<br>(T, TM, P, CO, G, MCO, TS23) | 0 Hz ÷ 600 Hz<br>(by steps of 10 Hz) | This parameter defines the maximum motor speed. |
| **CONF.POSITIVE LC**<br>(A) | 0 ÷ 2<br>(steps of 1) | This parameter defines the positive supply configuration for the main-contactor coil. Factory adjusted.<br>**0 =** The positive supply of Main Contactor coil is connected to PEB A2 (A19).<br>**1 =** The positive supply of Main Contactor coil is connected to KEY A10 (A8).<br>**2 =** The positive supply of Main Contactor coil is connected to SEAT/TILLER input A1 (A11).<br>NOTE: only Zapi technicians can change this value. |
| **POSITIVE E.B.**<br>(A) | 0 ÷ 2 | This parameter defines the hardware configuration for the positive terminal of the electromechanical brake PEB A2 (A19).<br>**0 =** PEB is managed by an internal high-side driver, supplied by PIN A3 (A1). This is the default configuration for ACEX NEW GENERATION Foc3 in the Zapi premium versions.<br>**1 =** PEB is externally connected to the SEAT/TILLER input A1 (A11).<br>**2 =** PEB is externally connected after the main contactor. This is the default configuration for ACEX NEW GENERATION Foc3 in the Zapi standard versions.<br>Note: By default, the high-side driver is not available in the standard versions. It can be added on request; in the Zapi standard configurations, the option 0 should be discussed with Zapi technicians in advance. |

### 8.2.6 HYDRO SETTING

| HYDRO SETTING | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **HYDRO TIME**<br>(T, TM, P) | 0 s ÷ 20 s<br>(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 FUNCTION**<br>(T, TM) | List of values | 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.<br>**NONE** = The traction controller does not manage any hydro function.<br>**KEYON** = The traction controller commands a separate unit to constantly drive the pump motor as long as the SEAT input A1 (A11) is active.<br>**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.<br>**OPTION#1** = The traction controller commands a separate unit to constantly drive the pump motor as long as the SEAT input A1 (A11) is active. At the same time, the controller activates a valve on output NEVP1 A24 (A1) at full set point.<br>**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 NEVP1 A24 (A1) 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 FEEDBACK SENSOR

The availability of the parameters described in this paragraph is related to the motor type and the position feedback sensor type. The acronyms used to indicate the motor type and the feedback sensor are:

- **AC** = asynchronous motor applications with encoder sensor.
- **BL all** = synchronous motor applications with all the position feedback sensors.
- **BL sin cos only** = synchronous motor applications with sin cos feedback sensor only.
- **BL 3-Hall only** = synchronous motor applications with six step feedback sensor only.
- **BL resolver only** = synchronous motor applications with external resolver interface only.
- **BL PWM only** = synchronous motor applications with PWM feedback sensor only.

| FEEDBACK SENSOR | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **ROTATION CW ENC**<br>(A)(AC) | OPTION#1, OPTION#2 | This parameter defines how the controller expects the encoder signals to be when the motor spins clockwise.<br>**OPTION#1 =** Channel B leads channel A.<br>**OPTION#2 =** Channel A leads channel B. |

| | | |
|---|---|---|
| **ROTATION CW MOT**<br>(A)(AC, BL all) | OPTION#1, OPTION#2 | This parameter defines the powering sequence of the motor phases in case of forward direction.<br>**OPTION#1 =** V leads U, U leads W.<br>**OPTION#2 =** W leads U, U leads V. |
| **ROTATION CW POS**<br>(A)(BL all) | 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.<br>Sin/cos case:<br>**OPTION#1 =** Sin leads cos.<br>**OPTION#2 =** Cos leads sin.<br>3-Hall case:<br>**OPTION#1 =** SH1 leads SH2, SH2 leads SH3.<br>**OPTION#2 =** SH3 leads SH2, SH2 leads SH1. |
| **FEEDBACK SENSOR**<br>(A)(AC, BL all) | 0 ÷ 7 | This parameter defines the type of the adopted speed sensor. Factory adjusted.<br>**0 =** Incremental encoder.<br>**1 =** Sin/cos sensor.<br>**2 =** Incremental encoder + sin/cos sensor.<br>**3 =** Incremental encoder + sin/cos sensor + index. Not applicable in ACEX NEW GENERATION Foc3.<br>**4 =** PWM absolute sensor + incremental encoder + index. Not applicable in ACEX NEW GENERATION Foc3.<br>**5 =** External resolver interface.<br>**6 =** 3-Hall sensor (six-step).<br>**7 =** PWM |
| **FEEDBACK POLES**<br>(A)(AC, BL all) | 1 ÷ 32<br>(steps of 1) | This parameter defines the number of poles per revolution of the motor position sensor. To be ignored in combination with encoders.<br>NOTE: the capability to use position sensors with a high number of poles may require a hardware customization. Ask to Zapi technicians for a feasibility check. |
| **DUTY PWM RANGE**<br>(A)(BL PWM only) | 0 % ÷ 25.5 %<br>(steps of 0.1 %) | This parameter defines the duty cycle range of the motor PWM feedback position sensor, expressed in terms of the deviation from the 0% and 100% duty cycle, assuming symmetry.<br>For example, if DUTY PWM RANGE is set to 5% (default value), it means that the duty cycle ranges from 5% up to 95%. |
| **ENCODER PULSES 1**<br>**ENCODER PULSES 2**<br>(A)(AC) | 32 ÷ 1024 | These parameters define the number of encoder pulses per revolution. They must be set equal otherwise the controller raises an alarm.<br>The available values are:<br>**32, 48, 64, 80, 96, 107, 124, 128, 143, 177, 256, 500, 512, 1000, 1024**<br>NOTE: it is possible to read encoders with a different number of pulses upon a SW customization. Ask to Zapi technicians for a feasibility check. |

| | | |
|---|---|---|
| **MOTOR P. PAIRS 1**<br>**MOTOR P. PAIRS 2**<br>(A)(AC, BL all) | 1 ÷ 28<br>(steps of 1) | These parameters define the number of pole pairs of the motor. They must be set equal otherwise the controller raises an alarm. |
| **DIAG.JUMP SENSOR**<br>(A)(AC, BL all) | 0 Hz ÷ 255 Hz<br>(steps of 1 Hz) | This parameter defines the maximum jump the speed feedback can perform within a hard-coded time interval (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**<br>(A)( AC, BL all) | 0 ms ÷ 255 ms<br>(steps of 1 ms) | This parameter defines the time constant of the software-level filter applied to the speed feedback. |
| **A.SENS.MAX SE**<br>(A)(BL sin cos, BL resolver) | 0 ÷ 1023<br>(steps of 1) | This parameter records the maximum voltage at the sine analog input during the auto-teaching procedure. This value is expressed as 10-bit digital units over the 0 V through 5 V range. |
| **A.SENS.MIN SE**<br>(A)( BL sin cos, BL resolver) | 0 ÷ 1023<br>(steps of 1) | This parameter records the minimum voltage at the sine analog input during the auto-teaching procedure. This value is expressed as 10-bit digital units over the 0 V through 5 V range. |
| **A.SENS.MAX CE**<br>(A)( BL sin cos, BL resolver) | 0 ÷ 1023<br>(steps of 1) | This parameter records the maximum voltage at the cosine analog input during the auto-teaching procedure. This value is expressed as 10-bit digital units over the 0 V through 5 V range. |
| **A.SENS.MIN CE**<br>(A)( BL sin cos, BL resolver) | 0 ÷ 1023<br>(steps of 1) | This parameter records the minimum voltage at the cosine analog input during the auto-teaching procedure. This value is expressed as 10-bit digital units over the 0 V through 5 V range. |
| **OFFSET ANGLE**<br>(A)(BL all) | -180° ÷ 180°<br>(steps of 0.01°) | This parameter gives the possibility to adjust the offset angle present between the absolute position sensor and the PMSM rotor orientation. It is automatically acquired by the ABS.SENS.ACQUIRE procedure (see 7.2.1). |
| **HYST. ANGLE**<br>(A)(BL 3-Hall only) | -180° ÷ 180°<br>(steps of 0.01°) | 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 acquired by the ABS.SENS.ACQUIRE procedure (see 7.2.1). |
| **SENSOR ANGLE DEL**<br>(A)(AC, BL all) | 0° ÷ 25.5°<br>(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. It is automatically acquired by the ABS.SENS.ACQUIRE procedure (see 7.2.1). |
| **ANGLE IDRMS COMP**<br>(A)(BL 3-Hall only) | 0° ÷ 25.5°<br>(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**<br>(A)(BL resolver only) | 0 V ÷ 70.4 V<br>(steps of 0.3 V) | Used for special resolvers. Reserved.<br>Note: only Zapi technicians can change this value. |

| | | |
|---|---|---|
| **ABS.SENS. ACQ.ID**<br>(T, P, CO, TM, TS23, G, MCO) (BL all) | 1% ÷ 100%<br>(steps of 1%) | This parameters defines the amount of current imposed by the motor controller during the acquisition of the signals from the motor position sensor.<br>It is defined as a percentage of the maximum current defined by the parameter SET CURRENT. |
| **ANGLE CORRECTION**<br>(A) **(**BL sin cos, BL resolver, BL PWM) | OFF, ON | This parameter enables the correction of the non-linearity error of the position sensor, in case a linearization of the position feedback is needed.<br>The correction map is defined by the COR ANGLE FEEDB table. |
| **FILTER FEEDBACK**<br>(A)(BL sin cos only) | OFF, ON | This parameter enables a software-level filter applied to the speed feedback. |
| **KP PLL FEEDBACK**<br>(A) ) (BL all) | 0 ÷ 255 | This parameter defines the proportional gain for the PLL (phase-locked loop) locked to the feedback position of the motor. |
| **KI PLL FEEDBACK**<br>(A) ) (BL all) | 0 ÷ 255 | This parameter defines the integral gain for the PLL (phase-locked loop) locked to the feedback position of the motor. |
| **ABS.SENS.ACQUIRE**<br>(A)(BL all) | OFF ÷ ON | This parameter activates the acquisition of the signals from the motor position sensor.<br>**<u>Contact Zapi technicians for a detailed description of the acquisition procedure</u>.** |
| **COR ANGLE FEEDB.**<br>**(Only in combination with sin/cos sensor or resolver)**<br>(A) **(**BL sin cos, BL resolver, BL PWM) | 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.<br>The correction has to be enabled by ANGLE CORRECTION. |

### 8.2.8 CURRENT PROFILE

*A wrong set up of the CURRENT PROFILE parameters may lead to malfunctioning and/or may decrease significantly the performance and the efficiency. CURRENT PROFILE submenu must only be accessed by skilled people.*

| **CURRENT PROFILE** | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **P0 IMAX MOT**<br>**P1 IMAX MOT**<br>**P2 IMAX MOT**<br>**P3 IMAX MOT**<br>(T, P, TM, CO, G, MCO, TS23) | 0% ÷ 100%<br>(steps of 1%) | These parameters define the motor current values for the four points of the motoring current profile described in paragraph 9.15. |

| | | |
|---|---|---|
| **P0 FREQ. MOT**<br>**P1 FREQ. MOT**<br>**P2 FREQ. MOT**<br>**P3 FREQ. MOT**<br>(T, P, TM, CO, G, MCO, TS23) | 0 Hz ÷ 1020 Hz<br>(255 steps) | These parameters define the frequency values for the four points of the motoring current profile described in paragraph 9.15. |
| **P0 IMAX BRK**<br>**P1 IMAX BRK**<br>**P2 IMAX BRK**<br>**P3 IMAX BRK**<br>(T, P, TM, CO, G, MCO, TS23) | 0% ÷ 100%<br>(steps of 1%) | These parameters define the motor current values for the four points of the braking current profile. |
| **P0 FREQ. BRK**<br>**P1 FREQ. BRK**<br>**P2 FREQ. BRK**<br>**P3 FREQ. BRK**<br>(T, P, TM, CO, G, MCO, TS23) | 0 Hz ÷ 1020 Hz<br>(255 steps) | These parameters define the frequency values for the four points of the braking current profile. |
| **MAX TORQUE REF**<br>(T, P, CO, TM, TS23, G, MCO) | 0 Nm ÷ 320 Nm<br>(steps of 2 Nm) | In torque control mode, this parameter defines the maximum torque the motor can provide given the current profile defined by the above parameters. |

### 8.2.9 PERFORM. ECONOMY

These parameters define the economy performance level; changing the performance level from normal to economy, the maximum traction/pump speed and the motor current profile are reduced in agreement with the following parameters.

| PERFORM. ECONOMY | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **ACC.TORQUE DEL.E**<br>(T, P, CO, TM, TS23, G, MCO) | 0.1 s ÷ 10 s<br>(steps of 0.1 s) | This parameter defines the acceleration ramp if TORQUE CONTROL is ON, i.e. the time needed to increase the torque from the minimum value up to the maximum one when the PERFORMANCE parameter is set to ECONOMY. |
| **ACCELER. DELAY E**<br>(T, P, CO, TM, G, MCO) | 0.1 s ÷ 25.5 s<br>(steps of 0.1 s) | This parameter defines the acceleration ramp, i.e. the time needed to speed up the motor from 0 Hz up to 100 Hz when the PERFORMANCE parameter is set to ECONOMY.<br>A special software feature manages the acceleration ramp depending on the speed setpoint (see paragraph 9.5). |
| **MAX SPEED FORW E**<br>(T, TM) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the maximum speed in forward direction as a percentage of TOP MAX SPEED when the PERFORMANCE parameter is set to ECONOMY. |
| **MAX SPEED LIFT E**<br>(P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the maximum speed of the pump motor during lift when the PERFORMANCE parameter is set to ECONOMY. It represents a percentage of the maximum voltage applied to the pump motor. |

| | | |
|---|---|---|
| **MAX SPEED BACK E**<br>(T, TM) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the maximum speed in backward direction as a percentage of TOP MAX SPEED when the PERFORMANCE parameter is set to ECONOMY. |
| **1ST PUMP SPEED E**<br>(P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the speed of the pump motor when 1st speed is requested and the PERFORMANCE parameter is set to ECONOMY. It represents a percentage of the maximum pump speed. |
| **2ND PUMP SPEED E**<br>(P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the speed of the pump motor when 2nd speed is requested and the PERFORMANCE parameter is set to ECONOMY. It represents a percentage of the maximum pump speed. |
| **3RD PUMP SPEED E**<br>(P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the speed of the pump motor when 3rd speed is requested and the PERFORMANCE parameter is set to ECONOMY. It represents a percentage of the maximum pump speed. |
| **4TH PUMP SPEED E**<br>(P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the speed of the pump motor when 4th speed is requested and the PERFORMANCE parameter is set to ECONOMY. It represents a percentage of the maximum pump speed. |
| **5TH PUMP SPEED E**<br>(P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the speed of the pump motor when 5th speed is requested and the PERFORMANCE parameter is set to ECONOMY. It represents a percentage of the maximum pump speed. |
| **HYD PUMP SPEED E**<br>(P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the speed of the pump motor used for the steering, when HYDRO FUNCTION is ON and when the PERFORMANCE parameter is set to ECONOMY. It represents a percentage of the maximum pump speed. |
| **P0 IMAX MOT E**<br>**P1 IMAX MOT E**<br>**P2 IMAX MOT E**<br>**P3 IMAX MOT E**<br>(T, P, TM, CO, G, MCO, TS23) | 0% ÷ 100%<br>(steps of 1%) | These parameters define the motor current values for the four points of the motoring current profile, described in paragraph 9.15, when the PERFORMANCE parameter is set to ECONOMY. |
| **P0 FREQ. MOT E**<br>**P1 FREQ. MOT E**<br>**P2 FREQ. MOT E**<br>**P3 FREQ. MOT E**<br>(T, P, TM, CO, G, MCO, TS23) | 0 Hz ÷ 1020 Hz<br>(255 steps) | These parameters define the frequency values for the four points of the motoring current profile, described in paragraph 9.15, when the PERFORMANCE parameter is set to ECONOMY. |

### 8.2.10 PERFORM. POWER

These parameters define the power performance level; changing the performance level from normal to power, the maximum traction/pump speed and the motor current profile are increased in agreement with the following parameters.

| PERFORM. POWER | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |

| | | |
|---|---|---|
| **ACC.TORQUE DEL.P**<br>(T, P, CO, TM, TS23, G, MCO) | 0.1 s ÷ 10 s<br>(steps of 0.1 s) | This parameter defines the acceleration ramp if TORQUE CONTROL is ON, i.e. the time needed to increase the torque from the minimum value up to the maximum one when the PERFORMANCE parameter is set to POWER. |
| **ACCELER. DELAY P**<br>(T, P, CO, TM, G, MCO) | 0.1 s ÷ 25.5 s<br>(steps of 0.1 s) | This parameter defines the acceleration ramp, i.e. the time needed to speed up the motor from 0 Hz up to 100 Hz when the PERFORMANCE parameter is set to POWER.<br>A special software feature manages the acceleration ramp depending on the speed setpoint (see paragraph 9.5). |
| **MAX SPEED FORW P**<br>(T, TM) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the maximum speed in forward direction as a percentage of TOP MAX SPEED when the PERFORMANCE parameter is set to POWER. |
| **MAX SPEED LIFT P**<br>(P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the maximum speed of the pump motor during lift when the PERFORMANCE parameter is set to POWER. It represents a percentage of the maximum voltage applied to the pump motor. |
| **MAX SPEED BACK P**<br>(T, TM) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the maximum speed in backward direction as a percentage of TOP MAX SPEED when the PERFORMANCE parameter is set to POWER. |
| **1ST PUMP SPEED P**<br>(P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the speed of the pump motor when 1st speed is requested and the PERFORMANCE parameter is set to POWER. It represents a percentage of the maximum pump speed. |
| **2ND PUMP SPEED P**<br>(P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the speed of the pump motor when 2nd speed is requested and the PERFORMANCE parameter is set to POWER. It represents a percentage of the maximum pump speed. |
| **3RD PUMP SPEED P**<br>(P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the speed of the pump motor when 3rd speed is requested and the PERFORMANCE parameter is set to POWER. It represents a percentage of the maximum pump speed. |
| **4TH PUMP SPEED P**<br>(P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the speed of the pump motor when 4th speed is requested and the PERFORMANCE parameter is set to POWER. It represents a percentage of the maximum pump speed. |
| **5TH PUMP SPEED P**<br>(P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the speed of the pump motor when 5th speed is requested and the PERFORMANCE parameter is set to POWER. It represents a percentage of the maximum pump speed. |
| **HYD PUMP SPEED P**<br>(P) | 0% ÷ 100%<br>(steps of 1%) | This parameter defines the speed of the pump motor used for the steering, when HYDRO FUNCTION is ON and when the PERFORMANCE parameter is set to POWER. It represents a percentage of the maximum pump speed. |
| **P0 IMAX MOT P**<br>**P1 IMAX MOT P**<br>**P2 IMAX MOT P**<br>**P3 IMAX MOT P**<br>(T, P, TM, CO, G, MCO, TS23) | 0% ÷ 100%<br>(steps of 1%) | These parameters define the motor current values for the four points of the motoring current profile, described in paragraph 9.15, when the PERFORMANCE parameter is set to POWER. |

| | | |
|---|---|---|
| **P0 FREQ. MOT P**<br>**P1 FREQ. MOT P**<br>**P2 FREQ. MOT P**<br>**P3 FREQ. MOT P**<br>(T, P, TM, CO, G, MCO, TS23) | 0 Hz ÷ 1020 Hz<br>(255 steps) | These parameters define the frequency values for the four points of the motoring current profile, described in paragraph 9.15, when the PERFORMANCE parameter is set to POWER. |

## 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 "Parameter" column, the availability field (between brackets), lists the controller types where the parameter is available. The controller type acronyms used to fill in the "Availability" field are:

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

The availability of the parameters is also related to the motor type and the position feedback sensor type. The acronyms used to indicate the motor type and the feedback sensor are:

**AC** = asynchronous motor applications with encoder sensor.
**BL all** = synchronous motor applications with all the position feedback sensors.
**BL sin cos only** = synchronous motor applications with sin cos feedback sensor only.
**BL 3-Hall only** = synchronous motor applications with six step feedback sensor only.
**BL resolver only** = synchronous motor applications with external resolver interface only.
**BL PWM only** = synchronous motor applications with PWM feedback sensor only.

### 8.3.1 TESTER – Master microcontroller

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

*In standard versions, a limited subset of these parameters is available.*

| TESTER (Master MCU) | | |
|---|---|---|
| **Parameter** | **Unit of measure (resolution)** | **Description** |
| **KEY VOLTAGE**<br>(A) | Volt (0.01 V) | KEY voltage A10 (A8) value measured in real time. |
| **BATTERY VOLTAGE**<br>(A) | Volt (0.01 V) | Battery voltage measured in real time across the DC-bus. |
| **DC BUS CURRENT**<br>(A) | | |
| **BATTERY CHARGE**<br>(A) | Percentage (1%) | Estimation of the battery charge based on the measure of the battery voltage. |
| **MOTOR VOLTAGE**<br>(A) | Percentage (1%) | Theoretical phase-to-phase voltage applied to the motor terminals.<br>The actual voltage delivered to the motor may be over-modulated or under-modulated in agreement with a dedicated parameter. Ask to Zapi technicians for more details. |
| **FREQUENCY**<br>(A) | Hertz (0.1 Hz) | Electrical frequency of the current sine-wave that the inverter is supplying to the motor. |
| **MEASURED SPEED**<br>(A) | Hertz (0.1 Hz) | Motor speed measured through the feedback sensor and expressed in the same unit of FREQUENCY (Hz). |
| **MEASURED SPD SLV**<br>(TM, MCO) | Hertz (0.1 Hz) | Motor speed of the traction slave controller in multi-motor applications. This speed is expressed in the same unit of FREQUENCY (Hz). |
| **SLIP VALUE**<br>(A)(AC motors only) | Hertz (0.01 Hz) | Motor slip, i.e. difference between the current frequency and the motor speed (in Hz). |
| **CURRENT RMS**<br>(A) | Ampere (1 A) | Root-mean-square value of the phase current supplied to the motor.<br>$Current\ [Arms] = \sqrt{{I_Q}^2 + {I_D}^2}$ |
| **CURRENT RMS SLV**<br>(TM, MCO) | Ampere (1 A) | Root-mean-square value of the traction slave controller phase current, in multi-motor applications.<br>$Current\ [Arms] = \sqrt{{I_Q}^2 + {I_D}^2}$ |
| **IMAX LIM. TRA**<br>(A) | Ampere (1 A) | Instantaneous value of the maximum current the inverter can apply to the motor to satisfy a traction request. The value is evaluated basing on the real-time conditions (inverter temperature, motor temperature, etc.). |
| **IMAX LIM. BRK**<br>(A) | Ampere (1 A) | Instantaneous value of the maximum current the inverter can apply to the motor to satisfy a braking request. The value is evaluated basing on the real-time conditions (inverter temperature, motor temperature, etc.). |

| TESTER (Master MCU) | | |
|---|---|---|
| **Parameter** | **Unit of measure (resolution)** | **Description** |
| **ID FILTERED RMS**<br>(A) | Ampere (1 A) | Projection of the current vector on the d-axis, expressed in root-mean-square Ampere. |
| **IQ FILTERED RMS**<br>(A) | Ampere (1 A) | Projection of the current vector on the q-axis, expressed in root-mean-square Ampere. |
| **FLAGS LIMITATION**<br>(A) | ON, OFF | 16-bit flags register. Any bit indicates the status (active/inactive) of a current limitation, for example the thermal current cutback, maximum current reached, etc…Ask to Zapi technicians for more details. |
| **MOT. POWER WATT**<br>(A) | Watt (1 W) | Estimation of the power supplied to the motor. |
| **STATOR FLUX MWB**<br>(A) | $10^{-3}$ Weber (0.1 mWb) | Estimation of the motor magnetic flux. |
| **MOTION TORQUE NM**<br>(A) | Nm (0.1 Nm) | Estimation of the motor torque. |
| **STEER ANGLE**<br>(T, TM, MCO) | Degrees (1°) | Steering angle from the sensor on the steered wheel or the steered axle. When the steering is straight ahead the STEER ANGLE is zero. |
| **INNER WHEEL RED.**<br>(TM, MCO) | Percentage (1%) | In multi-motors configurations, this parameter calculated by the master controller shows speed reduction of the inner wheel with respect to the turn the machine is making. |
| **TEMPERATURE**<br>(A) | Celsius degrees (1 °C) | Temperature measured on the inverter base plate.<br>This temperature is used for the HIGH TEMPERATURE alarm and the related thermal current cutback. |
| **MOTOR TEMPERAT.**<br>(A) | Celsius degrees (1 °C) | Motor-windings temperature.<br>This temperature is used for the MOTOR OVERTEMP alarm and the related thermal current cutback. |
| **DI0-A1/11 TIL SW**<br>(T, TM, TS1, G) | OFF/ON | Status of the TILLER/SEAT input A1 (A11). |
| **DI1-A7/5 QIPB SW**<br>(T, TM, G) | OFF/ON | Status of the quick-inversion/pedal-brake input A7 (A5). |
| **DI2-A6 HS SW**<br>(T, TM, G) | OFF/ON | Status of the hard and soft input A6. |
| **DI3-A32/22 FW SW**<br>**DI3-A32/22 ENAB.**<br>(T, TM, G) | OFF/ON<br>OFF/ON | Status of the forward-request input A32 (A22).<br>Status of the enable input A32 (A22). |
| **DI4-A31/21 BW SW**<br>(T, TM, G) | OFF/ON | Status of the backward-request input A31 (A21). |

| TESTER (Master MCU) | | |
|---|---|---|
| **Parameter** | **Unit of measure (resolution)** | **Description** |
| **DI3-A32/22 INC F** (TS1) | OFF/ON | Status of the forward-inching input A32 (A22). |
| **DI4-A31/21INC B** (TS1) | OFF/ON | Status of the backward-inching input A31 (A21). |
| **DI5-A19 HORN** (T, TM, G) | OFF/ON | Status of the horn request input A19. |
| **DI6-A20/14 LO DC** (T, TM, G) | OFF/ON | Status of the lowering-request input A20 (A14) that enables EVP1 and EVP2. |
| **A35/15-10-4 L DC** (T, TM, G) | OFF/ON | Status of the lift request input A35 (A15/A10/A4) that enables EV3. |
| **A35/15-10-4 ENDC** (T, TM, G) | OFF/ON | Status of the DC pump enable A35 (A15). COMBIACEX NEW GENERATION inverter only. |
| **DI8-A17 SPD1 DC** (T, TM, G) | OFF/ON | Status of the AUX1 input A17 that enables EV1 |
| **DI9-A29 PURID DC** (T, TM, G) | OFF/ON | Status of the free input A29. |
| **DI10-A16 SPD2 DC** (T, TM, G) | OFF/ON | Status of the AUX2 input A16 that enables EV2 |
| **A18-13/12-4 CTB1** (T, TM, G) ([1]) | OFF/ON | Status of the cutback speed 1 input A18/A13 (A12/A4). |
| **DI12-A21 CUTBAC2** (T, TM, G) ([1]) | OFF/ON | Status of the cutback speed 2 input A21. |
| **DI0-A1/11 SEAT** (P) | OFF/ON | Status of the TILLER/SEAT input A1 (A11). |
| **DI1-A7/5 SPD1** (P) | OFF/ON | Status of the 1ST-speed input A7 (A5). |
| **DI2-A6 HYDRO SW** (P) | OFF/ON | Status of the hydraulic-steering input A6. |
| **DI3-A32/22 LFT/E SW** (P) | OFF/ON | Status of the lift-request input A32 (A22). |
| **DI4-A31/21 LOWER** (P) | OFF/ON | Status of the lowering-request input A31 (A21). |

| TESTER (Master MCU) | | |
|---|---|---|
| **Parameter** | **Unit of measure (resolution)** | **Description** |
| **DI5-A19 SPD2 SW** (P) | OFF/ON | Status of the 2ND-speed input A19. |
| **DI6-A20/14 FREE** (P) | OFF/ON | Status of the free input A20 (A14). |
| **DI7-A35/15 SPD3** (P) | OFF/ON | Status of the 3RD-speed input A35 (A15). |
| **DI8-A17 SPD4 SW** (P) | OFF/ON | Status of the 4TH-speed input A17. |
| **DI9-A29 SPD5 SW** (P) | OFF/ON | Status of the 5TH speed input A29. |
| **DI10-A16 CUTBAC1** (P) | OFF/ON | Status of the speed-reduction input A16. |
| **DI11-A18/12** (P) ([1]) | OFF/ON | Status of the free input A18/A13 (A12/A4). |
| **DI12-A21 FREE** (P) ([1]) | OFF/ON | Status of the free input A21. |
| **NODE ID** (CO, MCO, SCO) | 0 ÷ 126 | Node ID of the controller over CAN bus. |
| **STO IN1** (CO) | OFF/ON | Status of the normally open safe torque off input 1 A35 |
| **STO IN2** (CO) | OFF/ON | Status of the normally closed safe torque off input 2 A17 |
| **SS1 IN1** (CO) | OFF/ON | Status of the normally open safe stop input 1 A19 |
| **SS1 IN2** (CO) | OFF/ON | Status of the normally closed safe stop input 2 A16 |
| **RESET SS1-STO AL** (CO) | OFF/ON | Status of the SS1-STO alarm reset input A29 |
| **TARGET SPEED** (CO, MCO) | Hertz (0.1 Hz) | Speed setpoint transmitted over CAN bus. It is expressed in tenths of Hz. |
| **BRAKING REQUEST** (CO, MCO) | 0 ÷ 255 | Braking setpoint transmitted over CAN bus. |

| TESTER (Master MCU) | | |
|---|---|---|
| **Parameter** | **Unit of measure (resolution)** | **Description** |
| **CONTROL WORD**<br>(CO, MCO, SCO, G) | 0 ÷ 65535 | Control word transmitted over CAN bus. |
| **CONTROL WORD 2**<br>(CO, MCO) | 0 ÷ 65535 | Control word 2 transmitted over CAN bus. |
| **STATUS WORD**<br>(CO, MCO, SCO, G) | 0 ÷ 65535 | Status word transmitted over CAN bus. |
| **WARNING SYSTEM**<br>(CO, MCO, SCO, G) | 0 ÷ 65535 | Warning code transmitted over CAN bus in case the inverter enters a warning status. |
| **TARGET EVP1**<br>(CO, MCO, SCO) | % (1%) | Setpoint of the proportional electrovalve EVP1 A24 (A1) transmitted over CAN bus. |
| **TARGET EVP2**<br>(CO, MCO, SCO) | % (1%) | Setpoint of the proportional electrovalve EVP2 A23 transmitted over CAN bus. |
| **TORQUE REQ.**<br>(CO, MCO) | % (255 steps) | Torque setpoint of the AC motor transmitted over CAN bus, expressed as a percentage of the maximum torque. |
| **TORQUE BRK REQ.**<br>(CO, MCO) | % (255 steps) | Breaking torque setpoint of the AC motor transmitted over CAN bus, expressed as a percentage of the maximum torque. |
| **A15/9 POT#1**<br>(A) | Volt (0.01 V) | Voltage of the analog input 1 A15 (A9). |
| **A30/20 POT#2**<br>(A) | Volt (0.01 V) | Voltage of the analog input 2 A30 (A20). |
| **D11-A18/12 POT#3**<br>(A) | Volt (0.01 V) | Voltage of the analog signal on pin A18 (A12). Please, note that depending on your hardware configuration, this pin may also be used as a cutback1 input, or as a sine feedback input or as a Hall sensor signal 1 input. |
| **D12-A21/15 POT#4**<br>(A) | Volt (0.01 V) | Voltage of the analog signal on pin A21 (A15). Please, note that depending on your hardware configuration, this pin may also be used as a cutback2 input, or as a cosine feedback input or as a lift digital input. |
| **SIN FB. INPUT**<br>(A) (BL sin cos and BL resolver only) | Volt (0.01 V) | Voltage of sine signal on A18 (A12). |
| **COS FB. INPUT**<br>(A) (BL sin cos and BL resolver only) | Volt (0.01 V) | Voltage of cosine signal on A21 (A15). |
| **A24/1 SET EVP**<br>(A) | % (1%) | Setpoint of proportional electrovalve EVP1. Pin A24 (A1). |

| TESTER (Master MCU) | | |
|---|---|---|
| **Parameter** | **Unit of measure (resolution)** | **Description** |
| **A24/1 CURR. EVP** (A) | $10^{-3}$ Ampere (1 mA) | Current flowing through the proportional electrovalve EVP1 connected to pin A24 (A1). |
| **A23 SET EVP2** (A) | % (1%) | Setpoint of proportional electrovalve EVP2. Pin A23. |
| **A23 CURRENT EVP2** (A) | $10^{-3}$ Ampere (1 mA) | Current flowing through the proportional electrovalve EVP2 connected to pin A23. |
| **A9/7 OUTPUT EV1** (A) | OFF/ON | Status of the EV1 output A9 (A7). |
| **A11 OUTPUT EV2** (A) | OFF/ON | Status of the EV2 output A11. |
| **A33/23 OUT. EV3** (A) | OFF/ON | Status of the EV3 output A33 (A23). |
| **A34 OUTPUT EV4** (A) | OFF/ON | Status of the EV4 output A34. |
| **A8/6 OUTPUT EV5** (A) | OFF/ON | Status of the EV5 output A8 (A6). Please, note that depending on your hardware configuration, this pin may be used as a positive supply for the potentiometers and/or for the motor feedback sensor. |
| **A26 OUTPUT EV6** (A) | OFF/ON | Status of the EV6 output A26. |
| **A12/16 MAIN CONT** (A) | % (1%) | Voltage applied over the main contactor coil. It corresponds to the duty cycle value of the PWM applied, expressed as percentage. |
| **A4/2 ELEC.BRAKE** (A) | % (1%) | Voltage applied over the electromechanical brake coil. It corresponds to the duty cycle value of the PWM applied, expressed as percentage. |
| **BYTE 4 PDO1TX** (CO, MCO) | 0 ÷ 255 | Byte 4 of the PDO1 message transmitted over Can bus. |
| **BYTE 5 PDO1TX** (CO, MCO) | 0 ÷ 255 | Byte 5 of the PDO1 message transmitted over Can bus. |
| **BYTE 6 PDO1TX** (CO, MCO) | 0 ÷ 255 | Byte 6 of the PDO1 message transmitted over Can bus. |
| **BYTE 7 PDO1TX** (CO, MCO) | 0 ÷ 255 | Byte 7 of the PDO1 message transmitted over Can bus. |
| **BYTE 2 PDO2TX** (CO, MCO) | 0 ÷ 255 | Byte 2 of the PDO2 message transmitted over Can bus. |

| TESTER (Master MCU) | | |
|---|---|---|
| **Parameter** | **Unit of measure (resolution)** | **Description** |
| **BYTE 5 PDO2TX**<br>(CO, MCO) | 0 ÷ 255 | Byte 5 of the PDO2 message transmitted over Can bus. |
| **WORD 6 PDO2TX**<br>(CO, MCO) | 0 ÷ 65535 | Bytes 6 and 7 of the PDO2 message transmitted over Can bus. |
| **CTRAP HW**<br>(A) | Decimal (1) | Counter showing the number of occurrences of hardware-overcurrent situations. |
| **TRUCK SPEED**<br>(T, TM, CO, MCO) | km/h (0.1 km/h) | Speed of the truck (it requires custom software embedding the gear ratio and the wheels radius). |
| **ODOMETER KM**<br>(T, TM, CO, MCO) | km (1 km) | Odometer: overall distance traveled by the truck. |
| **CPU TIME F US**<br>(A) | - | Reserved for Zapi technicians use. |
| **CPU TIME M US**<br>(A) | - | Reserved for Zapi technicians use. |
| **RESOLVER PULSE**<br>(A) (BL resolver only) | - | Used for special resolvers. Reserved for Zapi technicians use. |
| **SIXSTEP STATE**<br>(A) (BL 3-HS only) | 0 ÷ 7 | Used for six step sensors. Status of the three-Hall sensors coded as three binary digits. |
| **PERFORMANCE**<br>(A) | 0 ÷ 2 | Performance level:<br>**0 =** ECONOMY<br>**1 =** NORMAL<br>**2 =** POWER |
| **COUNT BUSOFF EX**<br>(A) | 0 ÷ 255 | Counter showing the number of external CAN bus-off state occurrences. The bus-off state is activated if the Transmit Error Counter equals or exceeds the SW predefined threshold. |
| **COUNT BUSWARN EX**<br>(A) | 0 ÷ 255 | Counter showing the number of external CAN bus warning state occurrences. The bus warning status is activated when the internal transmit/receive error counters equal or exceed the SW predefined threshold. |
| **COUNT BUSOFF IN**<br>(A) | 0 ÷ 255 | Counter showing the number of internal CAN bus-off state occurrences. The bus-off state is activated if the Transmit Error Counter equals or exceeds the SW predefined threshold.<br>The internal CAN bus is not accessible by external nodes; it is an internal CAN bus used to exchange data between the master MCU and the supervisor MCU. |

| TESTER (Master MCU) | | |
|---|---|---|
| **Parameter** | **Unit of measure (resolution)** | **Description** |
| **COUNT BUSWARN IN**<br>(A) | 0 ÷ 255 | Counter showing the number of internal CAN bus warning state occurrences. The bus warning status is activated when the internal transmit/receive error counters equal or exceed the SW predefined threshold.<br>The internal CAN bus is not accessible by external nodes; it is an internal CAN bus used to exchange data between the master MCU and the supervisor MCU. |

*([1]) The function associated to this parameter may not be available in certain motor type and position feedback sensor configurations. Please, refer to the connection drawings in the paragraph 3.2.*

### 8.3.2 TESTER – Supervisor microcontroller

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

| TESTER (Supervisor MCU) | | |
|---|---|---|
| **Parameter** | **Unit of measure (resolution)** | **Description** |
| **MEASURED SPEED** (A) | Hertz (0.1 Hz) | Motor speed measured through the feedback sensor and expressed in the same unit of FREQUENCY (Hz). |
| **DI0-A1/11** (A) | OFF/ON | Status of the digital input on pin A1 (A11). |
| **DI1-A7/5** (A) | OFF/ON | Status of the digital input on pin A7 (A5). |
| **DI2-A6** (A) | OFF/ON | Status of the digital input on pin A6. |
| **DI3-A32/22** (A) | OFF/ON | Status of the digital input on pin A32 (A22). |
| **DI4-A31/21** (A) | OFF/ON | Status of the digital input on pin A31 (A21). |
| **DI5-A19** (A) | OFF/ON | Status of the digital input on pin A19. |
| **DI6-A20/14** (A) | OFF/ON | Status of the digital input on pin A20 (A14). |
| **DI7-A35/15** (A) | OFF/ON | Status of the digital input on pin A35 (A15). |
| **DI8-A17** (A) | OFF/ON | Status of the digital input on pin A17. |
| **DI9-A29** (A) | OFF/ON | Status of the digital input on pin A29. |
| **DI10-A16** (A) | OFF/ON | Status of the digital input on pin A16. |
| **DI11-A18/12** (A) (AC only) | OFF/ON | Status of the cutback speed 1 input A18 (A12). |
| **DI12-A21** (A) (AC only) | OFF/ON | Status of the cutback speed 2 input A21. |
| **A15/9 POT#1** (A) | Volt (0.01V) | Voltage of the analog input 1 pin A15 (A9). |

| TESTER (Supervisor MCU) | | |
|---|---|---|
| **Parameter** | **Unit of measure (resolution)** | **Description** |
| **A30/20 POT#2**<br>(A) | Volt (0.01V) | Voltage of the analog input 2 pin A30 (A20). |
| **D11-A18/12 POT#3**<br>(A) | Volt (0.01V) | Voltage of the analog signal on pin A18 (A12). Please, note that depending on your hardware configuration, this pin may also be used as a cutback1 input, or as a sine feedback input or as a Hall sensor signal 1 input. |
| **D12-A21/15 POT#4**<br>(A) | Volt (0.01V) | Voltage of the analog signal on pin A21 (A15). Please, note that depending on your hardware configuration, this pin may also be used as a cutback2 input, or as a cosine feedback input or as a lift digital input. |
| **WARNING SYSTEM**<br>(CO, MCO) | 0 ÷ 65535 | Warning code transmitted over CAN bus (in case of warning). |
| **SIN FB. INPUT**<br>(A) (BL sin cos and BL resolver only) | Volt (0.01 V) | Voltage of sine signal on A18 (A12). |
| **COS FB. INPUT**<br>(A) (BL sin cos and BL resolver only) | Volt (0.01 V) | Voltage of cosine signal on A21 (A15). |
| **SIXSTEP STATE**<br>(A) (BL 3-HS only) | 0 ÷ 7 | Used for six-step sensors. Status of the three-Hall sensors coded as three binary digits. |
| **PERFORMANCE**<br>(A) | 0 ÷ 2 | Performance level:<br>**0 =** ECONOMY<br>**1 =** NORMAL<br>**2 =** POWER |
| **COUNT BUSOFF EX**<br>(A) | 0 ÷ 255 | Counter showing the number of external CAN bus-off state occurrences. The bus-off state is activated if the Transmit Error Counter equals or exceeds the SW predefined threshold. |
| **COUNT BUSWARN EX**<br>(A) | 0 ÷ 255 | Counter showing the number of external CAN bus warning state occurrences. The bus warning status is activated when the internal transmit/receive error counters equal or exceed the SW predefined threshold. |
| **COUNT BUSOFF IN**<br>(A) | 0 ÷ 255 | Counter showing the number of internal CAN bus-off state occurrences. The bus-off state is activated if the Transmit Error Counter equals or exceeds the SW predefined threshold.<br>The internal CAN bus is not accessible by external nodes; it is an internal CAN bus used to exchange data between the master MCU and the supervisor MCU. |

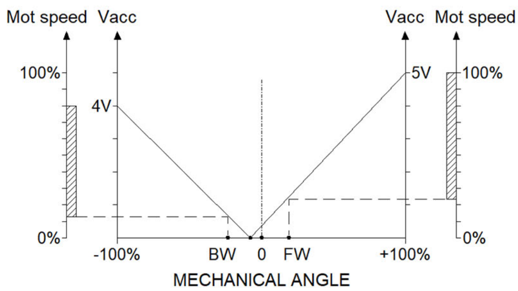
| TESTER (Supervisor MCU) | | |
|---|---|---|
| **Parameter** | **Unit of measure (resolution)** | **Description** |
| **COUNT BUSWARN IN**<br>(A) | 0 ÷ 255 | Counter showing the number of internal CAN bus warning state occurrences. The bus warning status is activated when the internal transmit/receive error counters equal or exceed the SW predefined threshold.<br>The internal CAN bus is not accessible by external nodes; it is an internal CAN bus used to exchange data between the master MCU and the supervisor MCU. |

# 9 OTHER FUNCTIONS

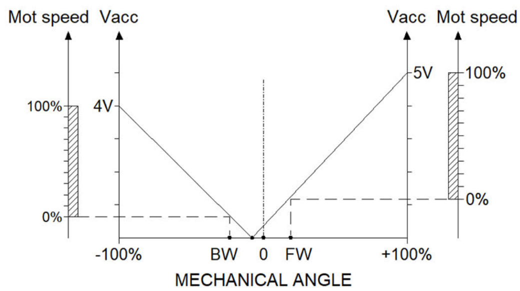
## 9.1 PROGRAM VACC function

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.




*Before 'PROGRAM VACC'.*




*After 'PROGRAM VACC'.*

PROGRAM VACC 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 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 sub-menu and they are:

- MIN LOWER
- MAX LOWER

See paragraphs 13.1.6 and 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 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 sub-menu and they are:

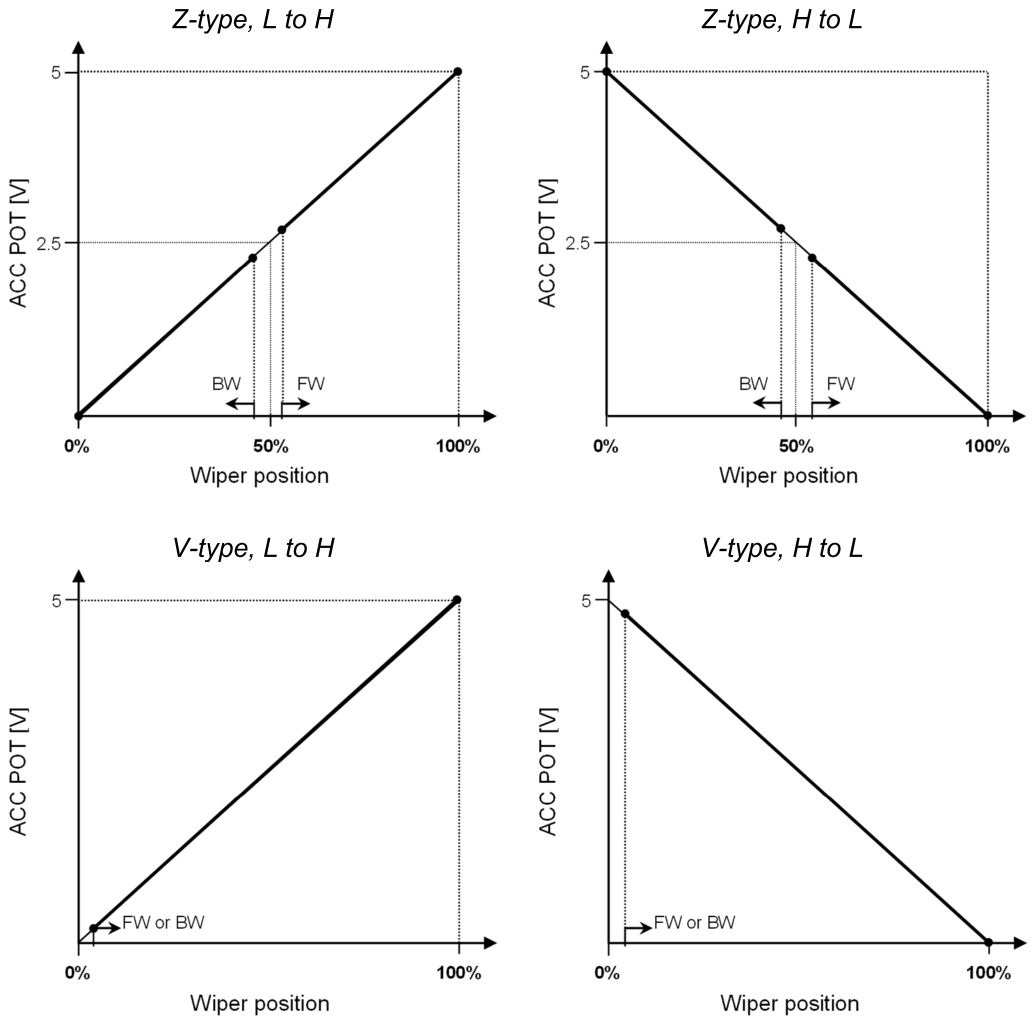
- STEER RIGHT VOLT
- STEER LEFT VOLT
- STEER ZERO VOLT

See paragraphs 13.1.7 or 13.2.9 for the acquisition procedure.

## 9.4 Potentiometer types

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

The following figures 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 Z-type potentiometers, both the speed setpoint and the travel direction are defined by the wiper position; the direction switches are not mandatory.*

*Adopting V-type potentiometers, only the speed setpoint is defined by the potentiometer and a couple of direction switches are mandatory, except those applications where only one direction is needed (for example only lift in pump applications).*

## 9.5 Acceleration modulation

The ACCELER. DELAY and ACC**.** MIN MODUL parameters define the acceleration rate associated with the speed setpoint variation when the acceleration modulation feature is enabled by parameter ACCEL MODULATION.

- **ACCEL MODULATION = OFF**
  Acceleration time can be obtained applying this formula:

$$Accel\ time\ [s] = \frac{\text{final speed setpoint [Hz]} - \text{measured speed [Hz]}}{100\ \text{Hz}} * ACCELER.DELAY\ [s]$$

- **ACCEL MODULATION = ON**
  The acceleration time imposed by software depends on the speed setpoint variation as following:

  Fast response:
  The speed setpoint variation is less than ACC. MIN MODUL. * 100 Hz.

  The acceleration rate is imposed by the ACCELER. DELAY parameter and the acceleration time results:

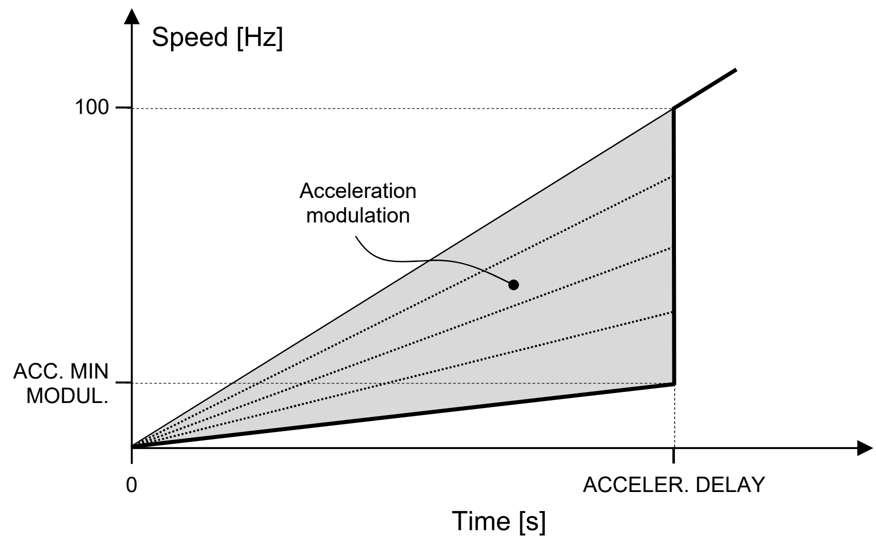
$$Accel\ time\ [s] = \frac{\text{final speed setpoint [Hz]} - \text{measured speed [Hz]}}{ACC.MIN\ MODUL. * 100\ Hz} * ACCELER.DELAY\ [s]$$

  Modulation (grey area):
  The speed setpoint variation is between ACC. MIN MODUL. * 100 Hz and 100 Hz.
  The acceleration rate is re-scaled so that the acceleration time results equal to the ACCELER. DELAY value.

  Wide variation:
  The speed setpoint variation is greater than 100 Hz.

  The acceleration rate is imposed by the ACCELER. DELAY parameter and the acceleration time results:

$$Accel\ time\ [s] = \frac{\text{final speed setpoint [Hz]} - \text{measured speed [Hz]}}{100\ \text{Hz}} * ACCELER.DELAY\ [s]$$




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

## 9.6 Deceleration modulation

The DECEL. BRAKING and ACC**.** MIN MODUL parameters define the deceleration rate associated with the speed setpoint variation upon a braking request when the acceleration modulation feature is enabled by parameter ACCEL MODULATION.

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

$$Decel\ time\ [s] = \frac{\text{measured speed [Hz]} - \text{final speed setpoint [Hz]}}{\text{100 Hz}} * DECEL.BRAKING\ [s]$$

– **ACCEL MODULATION = ON**
  The deceleration time imposed by software depends on the speed setpoint variation as following:

  <u>Fast response:</u>
  The required speed reduction is < ACC. MIN MODUL. * 100 Hz.

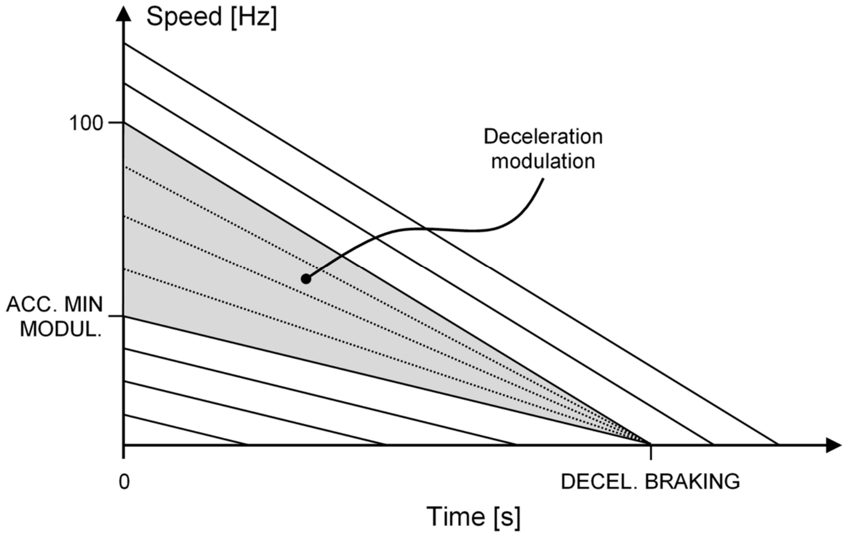
  The deceleration time results:

$$Decel\ time\ [s] = \frac{\text{measured speed [Hz]} - \text{final speed setpoint [Hz]}}{\text{ACC. MIN MODUL.} * \text{100 Hz}} * DECEL.BRAKING\ [s]$$

  <u>Modulation (grey area):</u>
  The required speed reduction is between ACC. MIN MODUL. * 100 Hz and 100 Hz.
  The deceleration rate is re-scaled so that the deceleration time results equal to DECEL. BRAKING.

  <u>Wide variation:</u>
  The required speed reduction is > 100 Hz.
  The deceleration time is results:

$$Decel\ time\ [s] = \frac{\text{measured speed [Hz]} - \text{final speed setpoint [Hz]}}{\text{100 Hz}} * DECEL.BRAKING\ [s]$$




*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

The RELEASE BRAKING and REL. MIN MODUL. parameters define the stopping rate associated with a travel release. The stopping time imposed by software depends on the speed setpoint variation as following:

Fast response:

The required speed reduction is < 100 Hz · REL. MIN MODUL.

The stopping time results:

$$Stop\ time\ [s] = \frac{\text{measured speed [Hz]} - \text{final speed setpoint [Hz]}}{\text{REL. MIN MODUL.} * \text{ 100 Hz}} * RELEASE\ BRAKING\ [s]$$

Modulation (grey area):

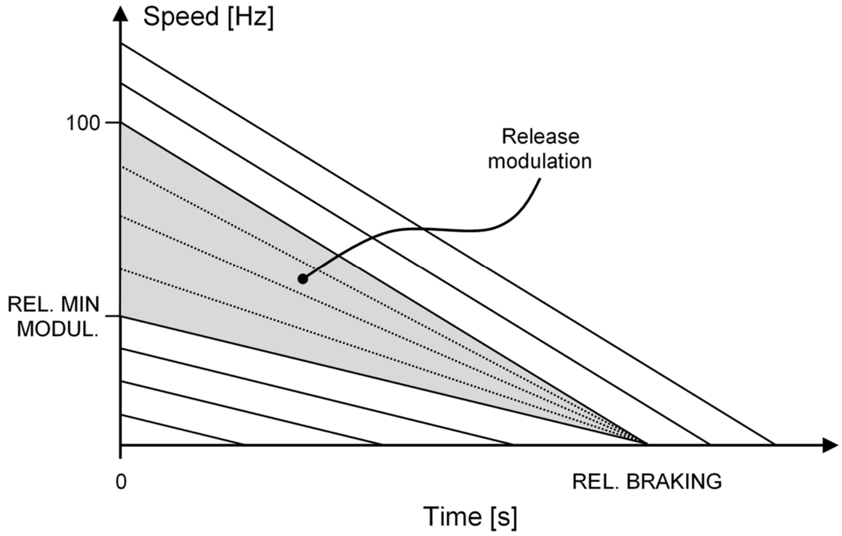
The required speed reduction is between 100 Hz · REL. MIN MODUL. and 100 Hz.
The stopping rate is re-scaled so that the stopping time results equal to RELEASE BRAKING.

Wide variation:

The required speed reduction is > 100 Hz

The stopping time results:

$$Stop\ time\ [s] = \frac{\text{measured speed [Hz]} - \text{final speed setpoint [Hz]}}{\text{100 Hz}} * RELEASE\ BRAKING\ [s]$$

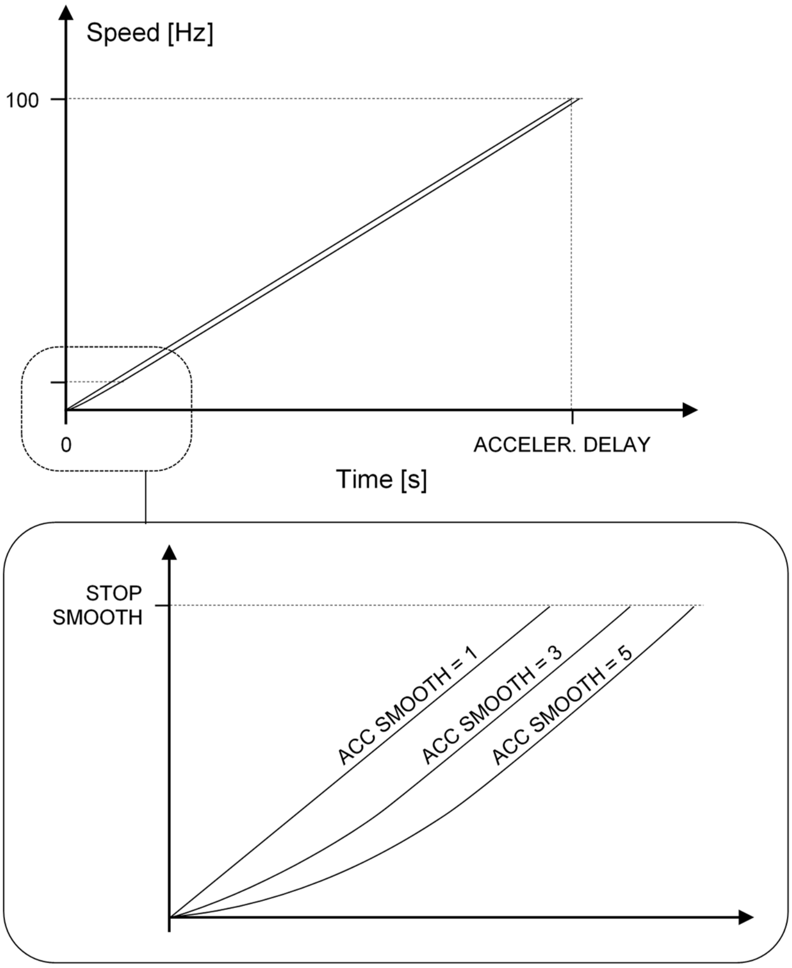


*Speed evolution during releases from positive speeds down to stationary.*

*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: 1 results in a linear ramp, higher values (up to 5) 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
- Permitted steering-wheel angles = -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 define the speed profile depicted in the graph below.

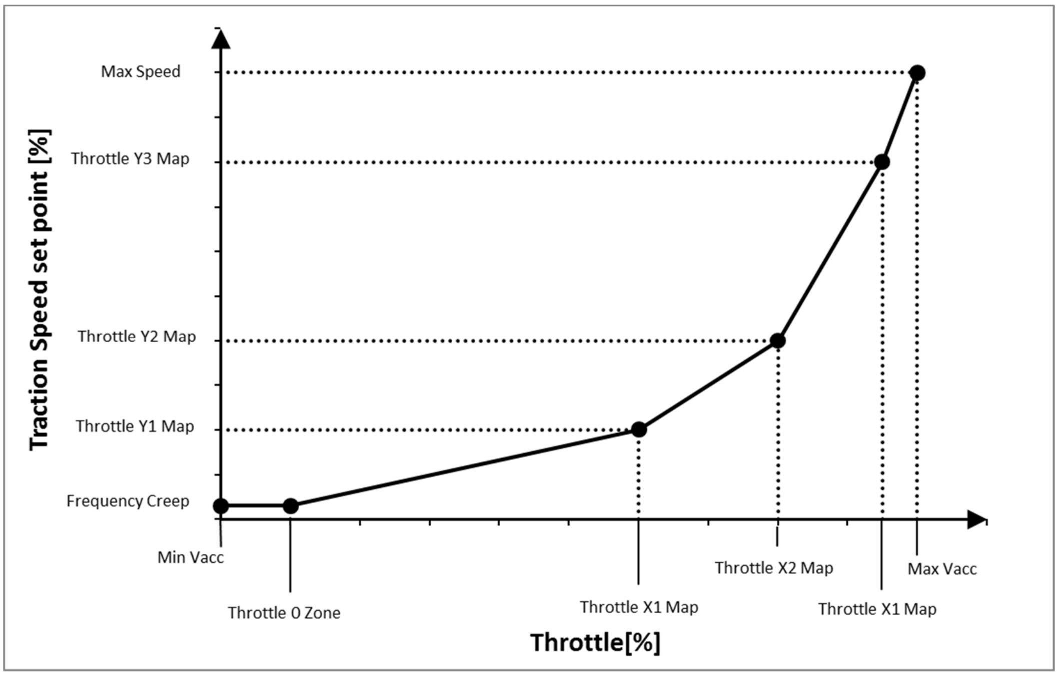

*Steering curve.*

## 9.10 Throttle profile

ACEX NEW GENERATION Foc3 performs the truck speed control along a polyline function of the accelerator position in order to provide a better resolution of the speed set-point at low speed. The relationship between the speed set-point and the throttle voltage follows the polyline function described by these parameters:

| Throttle signal<br>[% of MAX VACC] | Speed setpoint<br>[% of MAXIMUM 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<br>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.
The THROTTLE 0 ZONE defines a dead zone close to the neutral position.
For higher potentiometer voltages, the speed setpoint grows up as a polyline function. The following graph shows an example of 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 voltage controlled PWM-modulated outputs.

For both these outputs, there is the possibility to set the pull-in voltage and the retention voltage applied to the coil, via dedicated parameters under the SET OPTIONS list:

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

MC VOLTAGE [or EB VOLTAGE] parameter specifies the duty cycle applied in the first second of actuation and MC VOLT RED [or EB VOLT RED] determines the duty-cycle applied afterwards, necessary to keep the contactor closed [or brake disengaged], according to this formula:

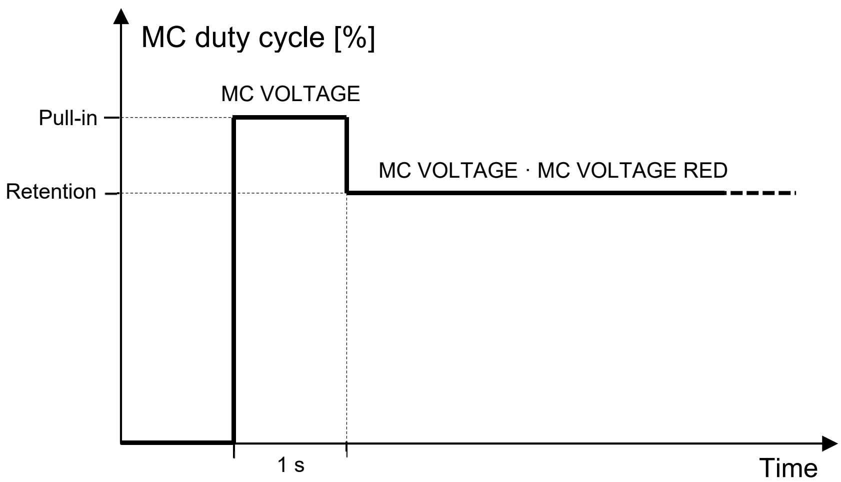
$$Final\ duty\ cycle\ [\%] = MC\ VOLTAGE\ \cdot MC\ VOLT\ RED$$

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

Contactor is closed by applying 100% of duty-cycle to the coil and after 1 second the duty cycle is reduced to 80%.

Example 2:
MC VOLTAGE = 80% ➲ Pull-in duty-cycle = 80%
MC VOLTAGE RED. = 100% ➲ Retention duty-cycle = 80% (80% x 100%).
Contactor is closed by applying 80% of duty-cycle to the coil and after 1 second the duty cycle is kept at the same value (80%).

Example 3:
MC VOLTAGE = 80% ➲ Pull-in duty-cycle = 80%
MC VOLTAGE RED. = 80% ➲ Retention duty-cycle = 64% (80% x 80%).
Contactor is closed by applying 80% of duty-cycle to the coil and after 1 second the duty cycle is reduced to 64% (80% of 8%).




*Main contactor output behavior.*

## 9.12 Battery-charge detection

Operating condition

In operating conditions, a software algorithm estimates the battery charge status as follows:

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 two user defined parameters:
   - BAT.MAX.ADJ that specifies the full-charge voltage (100% of charge)
   - BAT.MIN.ADJ. that specifies the discharged-battery voltage (10% of charge).

   These parameters are expressed as the percentage deviation with respect to the nominal battery voltage.

   Example:

– Nominal voltage: 48 V
– Full-charge voltage: 52 V
– Discharged-battery voltage (10%): 43 V
– BAT. MAX ADJ = (52 - 48) / 48 = +8.3%
– BAT. MIN ADJ. = (43 - 48) / 48 = -10.4%

3. The battery current is integrated over time for estimating the energy withdrawn from the battery in Ah.
4. The state of charge is dynamically updated basing on the comparison from step 2 and the energy estimation from step 3.

It is possible to adapt the battery-charge detection to your specific battery by changing BAT.MAX.ADJ and BAT.MIN.ADJ. parameters (e.g. if the battery-discharge detection occurs when the battery is not totally discharged, it is necessary to reduce BAT. MIN ADJ).

<u>Start-up</u>

At key-on, a software algorithm adjusts the level of the battery charge table as follows:

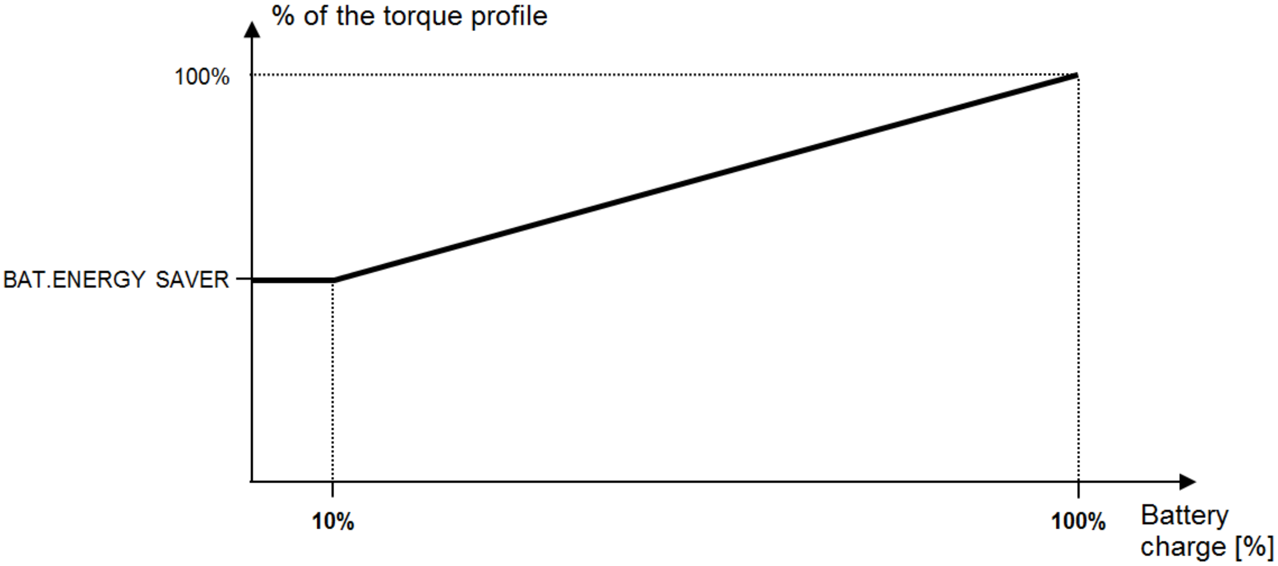
1) The battery voltage is read from the key input when the battery current is zero, which is when the output power stage is not driven. It is evaluated as the average value over a window of time.
2) The measured voltage is compared with a threshold value which comes as a function of the actual state of charge and the BDI ADJ STARTUP parameter that defines, in percentage, the start-up full-charge voltage deviation with respect to the nominal battery voltage. By default, it can be set at the same value as BAT. MAX ADJ. By the comparison, a new state of charge is obtained.
3) The minimum variation of the battery charge that can be detected at key-on depends on the BDI RESET parameter. Indeed, if the new battery charge percentage is within the range given by the previous percentage stored in EEPROM ± BDI RESET, it is discarded; otherwise the charge percentage is updated with the new value.

## 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. This parameter represents the percentage of the output torque profile applied when the battery charge falls below 10%.

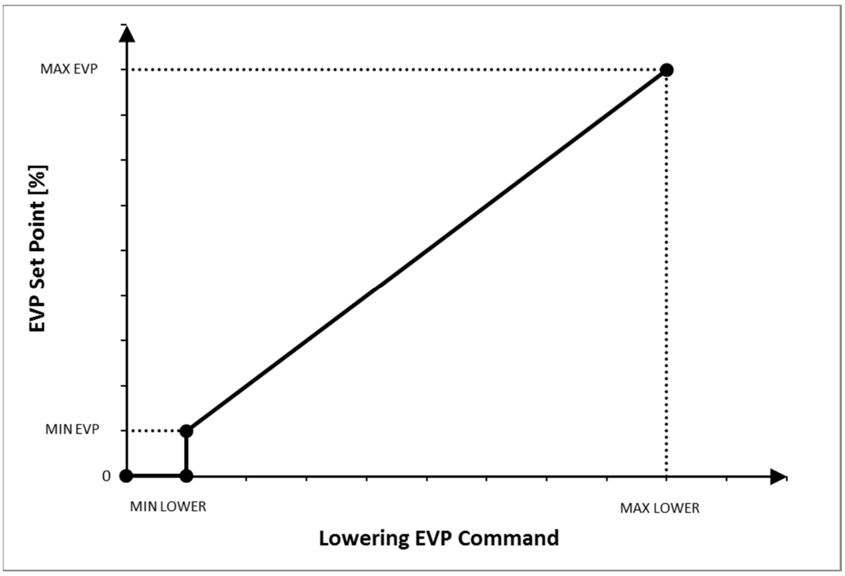
A linear reduction of the torque profile is performed scaling it down by a percentage from 100% down to BAT.ENERGY SAVER for charge values from 100% down to 10%, as depicted in the graph below. If the saving feature is not desired, BAT.ENERGY SAVER should be set equal to 100%.




*Torque reduction vs. battery charge.*

## 9.14 EVP Setup

When the EVP is set as ANALOG (see paragraph 8.2.2) the output is managed as explained in the following example.
Considering an EVP driving the lowering valve, the MIN EVP parameter (see paragraph 8.2.1) determines the minimum current set point applied to the valve when the position of the potentiometer is at the minimum (MIN LOWER) (see paragraph 8.2.1).
Then, the current set point applied to the valve increases proportionally with the potentiometer voltage up to the maximum (MAX EVP) (see paragraph 8.2.1), reached when the position of the potentiometer is at the maximum (MAX LOWER) (see paragraph 8.2.1).



*EVP management.*

If the valve is set as ON-OFF the MIN EVP parameter is disabled and, when the valve is activated, the current set point applied to the valve depends by the MAX EVP parameter only.

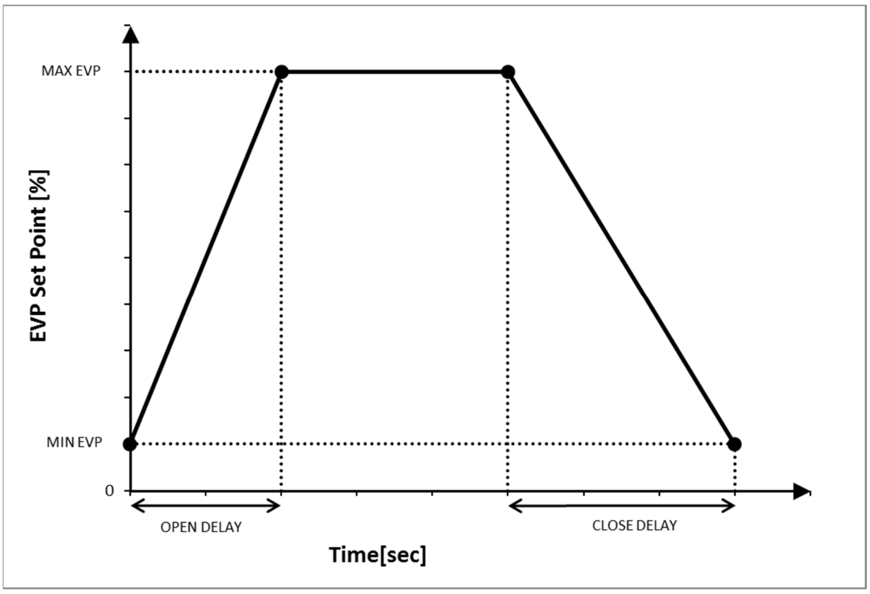
The dynamic behavior (delay seen during the modification of the current set point) in both cases, ANALOG valve and ON/OFF valve, can be adjusted using the OPEN DELAY and CLOSE DELAY parameters (see paragraph 8.2.1).

OPEN DELAY determines the current increase rate on EVP and it sets the time needed to increase the EVP current to the maximum permitted value.

CLOSE DELAY determines the current decrease rate on EVP and it sets the time needed to decrease the EVP current to the minimum permitted value.

**Example 1:**
The lowering output is set to ANALOG, the lowering digital input is active and the lowering request consists of a step with amplitude equal to MAX EVP – MIN EVP. The current, initially at the MIN EVP value, it is increased up to MAX EVP value in a time specified by the OPEN DELAY parameter.
In the same way, if the actual set point applied is at the maximum and the lowering request is removed (the lowering potentiometer is rotated back to its minimum), the EVP current is reduced to the minimum in a time specified by the CLOSE DELAY parameter.

**Example 2:**
The lowering output is set to ON/OFF. As soon as the lowering request is applied, the current will increase from zero to MAX EVP in a time frame correspondent to OPEN DELAY value.
In the same way, when the lowering request is removed, the set point current is reduced to zero in a time delay equal to CLOSE DELAY.



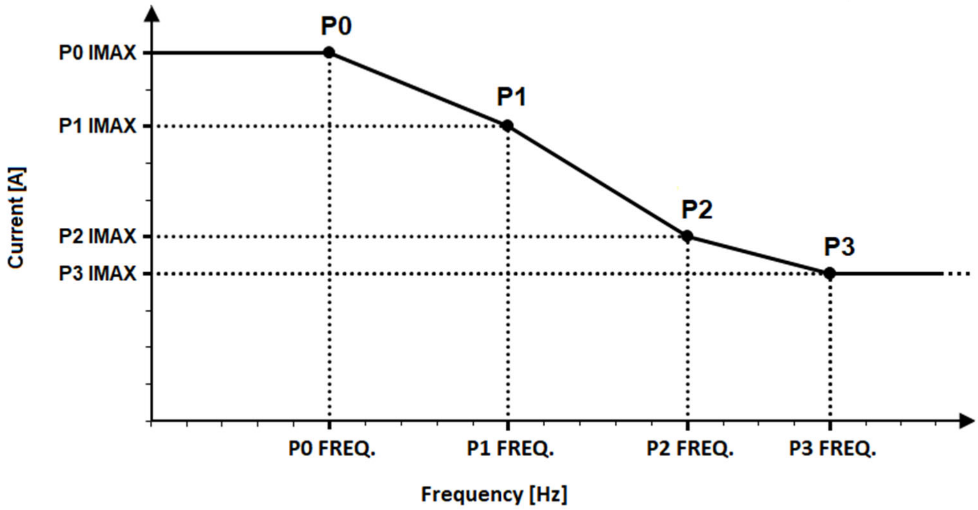

*EVP set point.*

## 9.15 Current Profile

Exploiting the CURRENT PROFILE list of parameters it is possible to limit the maximum current demand for matching two goals:

- Not overtaking the maximum torque profile of the motor.
- Imposing 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 pairs define two different current profiles, for motoring and braking respectively. Points P0 through P3 are expected to describe a descending current profile, otherwise the alarm CURRENT PROFILE is given. See paragraph 8.2.8.




*Current profile.*

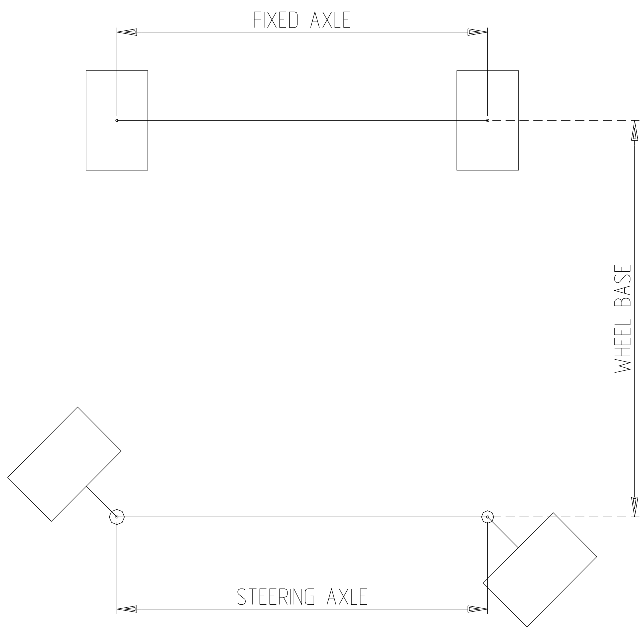
## 9.16 Steering table

Exploiting the steering table, the operator can calibrate the rotation applied to the steering wheels in order 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-wheels predefined steering table.
- **OPTION#2** = four-wheels predefined steering table




*Geometrical steering-related parameters.*

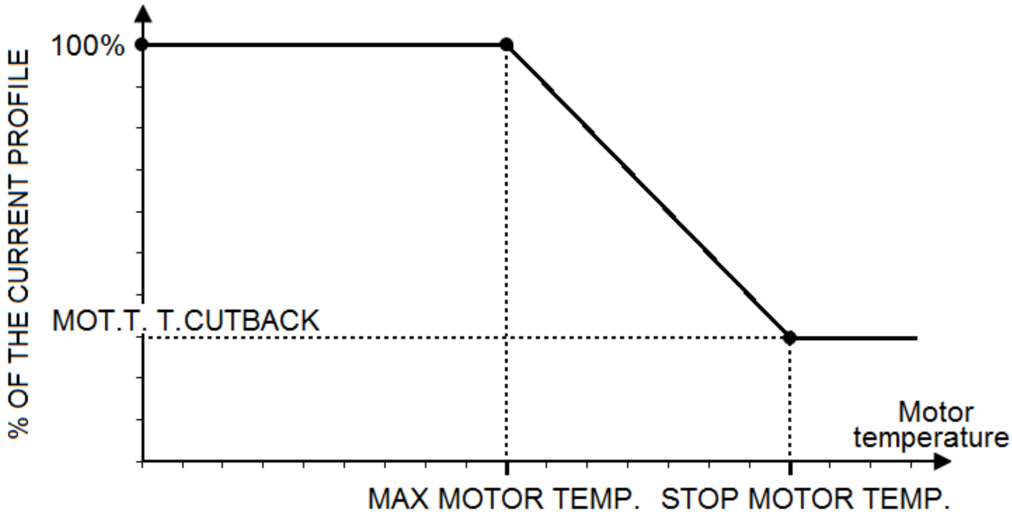
## 9.17 Motor thermal protection

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

The thermal protection feature can be customized by setting the parameters MAX. MOTOR TEMP., STOP MOTOR TEMP. and MOT.T. T.CUTBACK in the ADJUSTMENTS list.

A linear current reduction is performed for temperatures between MAX. MOTOR TEMP. and STOP MOTOR TEMP. The current profile (see paragraph 9.15) is linearly reduced from 100% of the imposed current profile down to MOT.T. T.CUTBACK.

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




*Current reduction for motor thermal protection.*

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

*In addition to the current cutback, for motor temperatures above MAX. MOTOR TEMP., the alarm MOTOR TEMPERAT. is raised and the electrical frequency is limited to 23 Hz maximum with a consequent speed reduction.*

*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.*

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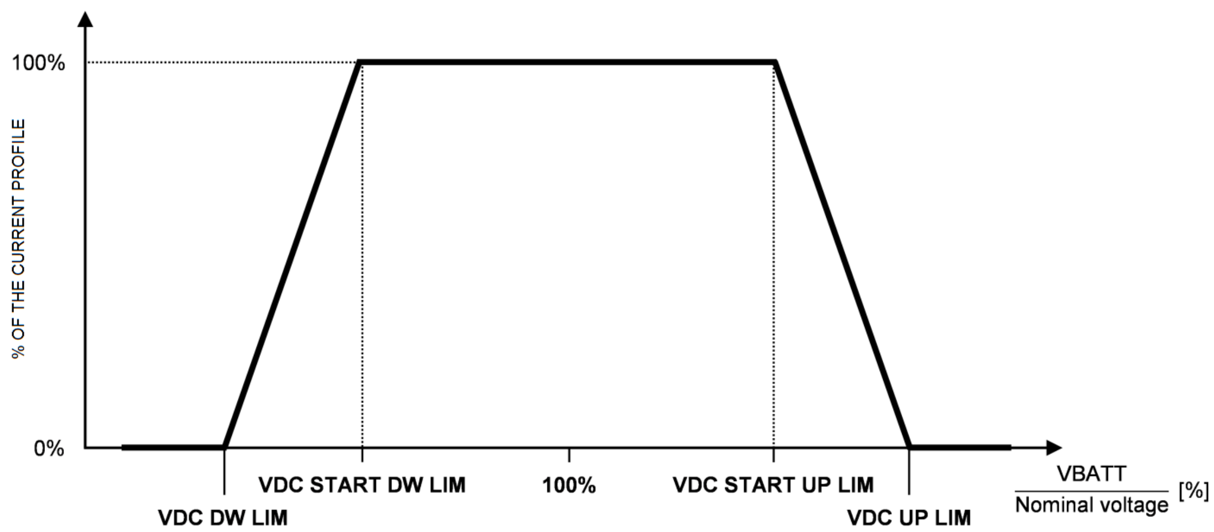
## 9.18 Overvoltage and under-voltage protection

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

Overvoltage and under-voltage limitations can be customized by setting the 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 current 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 current profile is clamped to zero. Normal operation at full current 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 current profile based on the battery voltage.*

## 9.19 Performance modes

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

- Economy
- Power

By default, the normal mode is selected. The performance mode can be changed from an external display or another master unit on the CAN bus network only if the PERFORMANCE parameter under the SET OPTIONS list is enabled. Parameters under PERFORM. ECONOMY and PERFORM. POWER lists define the economy and power modes settings (see paragraphs 8.2.9 and 8.2.10); these parameters 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.

# 10 DIAGNOSTIC SYSTEM

The diagnostic system of ACEX NEW GENERATION provides the operator with information about a wide set of faults or problems that the controller can encounter.

Faults related to hardware failures which prevent the motor from spinning or safety-related failures are managed by stopping the power bridge and, when possible, opening the main contactor and applying the electromechanical brake. Instead, in presence of minor issues that do not require stopping the power section, the controller keeps controlling the motor. Depending on the nature of the issue, preventive actions are taken 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:

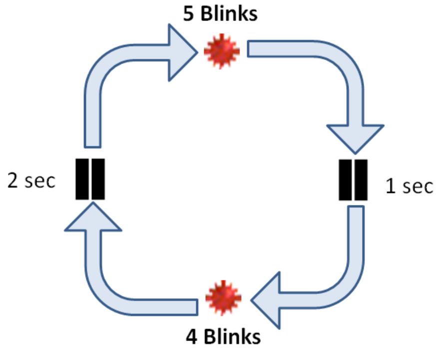
5. It blinks as many times as the first decimal digit.
6. It makes a pause of 1 sec.
7. It blinks as much times as the second decimal digit.

After a pause of 2 seconds, the sequence repeats.

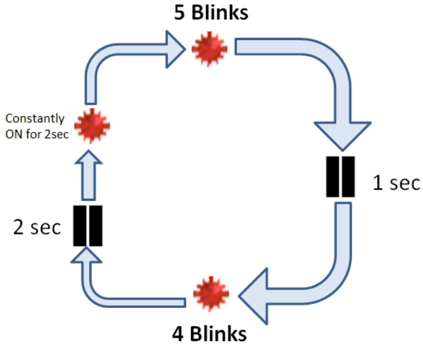
In case of faults from the supervisor microcontroller, the sequence is the same with the only difference that the LED stays ON for 2 sec before flashing the appropriate code.

Examples:

– Alarm 54 on master microcontroller




– Alarm 54 on supervisor microcontroller




## 10.3 Alarms from master MCU

| Error code | Effect | Condition | Restart procedure | MDI / LED CODE | CAN OPEN CODE | ZAPI CODE |
|---|---|---|---|---|---|---|
| WAITING FOR NODE | MC is opened, EB is applied, Traction/Pump and valves are disabled | Start-up, standby, running | Key re-cycle | 0 | 0000 | 224 |
| BATTERY LOW | According to parameter BATTERY CHECK (SET OPTIONS list, paragraph 8.2.2). MC is opened, EB is applied, traction/pump is disabled. | Start-up, standby, running | Battery recharge, key re-cycle | 0 | FF42 | 66 |
| DATA ACQUISITION | Traction is disabled | Controller calibration | Traction request | 0 | 0000 | 247 |
| CHECK UP NEEDED | A warning is shown in the display | Start-up | Check-up done, key re-cycle | 0 | 0000 | 249 |
| RPM HIGH | MC is opened, Traction/Pump is disabled | Running | Key re-cycle | 0 | FFA1 | 161 |

| Error code | Effect | Condition | Restart procedure | MDI / LED CODE | CAN OPEN CODE | ZAPI CODE |
|---|---|---|---|---|---|---|
| WRONG PERFORM. | Traction is disabled | Start-up, standby, running | Traction request | 0 | FF95 | 149 |
| WARNING SLAVE | MC is opened, EB is applied, Traction/Pump is disabled | Start-up, standby, running | Key re-cycle | 1 | FF01 | 244 |
| ACQUIRING A.S. | | Sensor Acquiring | | 2 | FFAB | 171 |
| ACQUIRE END | | Sensor Acquiring | Key re-cycle | 2 | FFAD | 173 |
| ACQUIRE ABORT | | Sensor Acquiring | Key re-cycle | 2 | FFAC | 172 |
| SPEED FB.ERR. XX | MC is opened, EB is applied, Traction/Pump is disabled | Running | Traction/Pump request | 3 | FFA8 | 168 |
| OFFSET SPD.SENS. | EB is applied, Traction/Pump is disabled | Start-up | Perform the absolute sensor acquisition procedure | 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 |
| ED SLIP MISMATCH | MC is opened, EB is applied, Traction/Pump is disabled | Running | Traction/Pump request | 7 | FFA3 | 163 |
| WATCHDOG | MC is opened, EB is applied, Traction/Pump and valves are disabled | Start-up, standby, running | Key re-cycle | 8 | 6010 | 8 |
| EVP DRIVER OPEN | EVP1 stopped, traction is allowed | Start-up, standby, running | EVP1 request | 9 | FFF8 | 240 |
| EVP COIL OPEN | EVP1 stopped, traction is allowed | Start-up, stand-by, running | EVP1 request | 9 | 5002 | 214 |
| EVP DRIV. SHORT. | EVP1 stopped, traction is allowed | Start-up, stand-by, running | EVP1 request | 9 | 5003 | 215 |
| EVP COIL SHORT. | EVP1 stopped, traction is allowed | Start-up, stand-by, running | EVP1 request | 9 | 5004 | 176 |
| EVP2 DRIVER OPEN | EVP2 stopped, traction is allowed | Start-up, stand-by, running | EVP2 request | 10 | FFB8 | 184 |
| EVP2 COIL OPEN | EVP2 stopped, traction is allowed | Start-up, stand-by, running | EVP2 request | 10 | 50F2 | 182 |
| EVP2 DRIV. SHORT. | EVP2 stopped, traction is allowed | Start-up, stand-by, running | EVP2 request | 10 | 50F3 | 183 |
| EVP2 COIL SHORT. | EVP2 stopped, traction is allowed | Start-up, stand-by, running | EVP2 request | 10 | 50F4 | 252 |
| STALL ROTOR | EB is applied, traction/pump is disabled | Running | Traction/Pump request | 11 | FFD3 | 211 |
| CONTROLLER MISM. | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Install the correct software and key re-cycle | 12 | FFEF | 239 |
| EEPROM KO | Controller works using the default parameters | Start-up, stand-by, running | | 13 | 3610 | 208 |
| PARAM RESTORE | No effect | Start-up | Traction/Pump request | 14 | 0000 | 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. XX | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Key re-cycle | 16 | FFEE | 238 |
| LOGIC FAILURE #3 | MC is opened, EB is applied, Traction/Pump and valves are disabled | Start-up, stand-by | Key re-cycle | 17 | FF11 | 17 |
| LOGIC FAILURE #2 | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up, stand-by | Key re-cycle | 18 | FF12 | 18 |
| LOGIC FAILURE #1 | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Stand-by, running | Key re-cycle | 19 | 5114 | 19 |

| Error code | Effect | Condition | Restart procedure | MDI / LED CODE | CAN OPEN CODE | ZAPI CODE |
|---|---|---|---|---|---|---|
| VKEY OFF SHORTED | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Key re-cycle | 20 | 5101 | 220 |
| CONT. DRV. EV | The valve is stopped, traction is allowed | Start-up, stand-by, running | Valve request | **21** | **FFE8** | **232** |
| DRV. SHOR. EV | The valve is stopped, traction is allowed | Start-up, stand-by, running | Valve request | **21** | **FFF9** | **234** |
| COIL SHOR. EVAUX | MC is opened, EB is applied, Traction/Pump and valves are 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 and valves are stopped (the command is released) | Start-up, Stand-by, running | Valves or Traction/Pump request | **21** | **FFF2** | **242** |
| LC COIL OPEN | MC is opened (the command is released), EB is applied, Traction/Pump and valves are disabled | Start-up, stand-by, running | Valves or Traction/Pump request | **22** | **FFE6** | **230** |
| IQ MISMATCHED | Traction/Pump is stopped, EB is applied. | Running | Traction/Pump request | **24** | **FFF5** | **245** |
| PEV NOT OK | Pump motor disabled, valves are disabled | Start-up, stand-by, running | Valves request | **25** | **FFDB** | **217** |
| AUX BATT. SHORT. | MC is opened (the command is released), EB is applied, Traction/Pump and valves are disabled | Start-up, stand-by, running | Check the POSITIVE E.B. parameter and key re-cycle | **27** | **5001** | **194** |
| INIT VMN LOW | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Valves or Traction/Pump request | **30** | **3121** | **207** |
| VMN LOW | MC is opened, EB is applied, Traction/Pump and valves are disabled | Start-up, stand-by | Valves or Traction/Pump request | **30** | **3120** | **30** |
| INIT VMN HIGH | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Valves or Traction/Pump request | **31** | **3111** | **206** |
| VMN HIGH | MC is opened, EB is applied, Traction/Pump and valves are disabled | Start-up, stand-by | Valves or Traction/Pump request | **31** | **3110** | **31** |
| 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 | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Key re-cycle | **32** | **FFE3** | **227** |
| HW FAULT EB. | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Key re-cycle | 34 | FFE5 | 229 |
| POSITIVE LC OPEN | MC is opened, EB is applied, Traction/Pump and valves are disabled | Start-up, stand-by, running | Valves or Traction/Pump request | 35 | FFD5 | 213 |
| FIELD ORIENT. KO | MC is opened, EB is applied, Traction/Pump and valves are disabled | Running | Valves or Traction/Pump request | 36 | FFFD | 253 |
| CONTACTOR CLOSED | MC is not closed (command is not activated), EB is applied, Traction/Pump and valves are disabled | Start-up | Valves or Traction/Pump request | 37 | 5442 | 37 |
| CONTACTOR OPEN | MC is opened, EB is applied, Traction/Pump and valves are disabled | Start-up, stand-by, running | Valves or Traction/Pump request | 38 | 5441 | 38 |
| POWER MISMATCH | MC is opened, EB is applied, Traction is disabled | Running | Traction/Pump request | 39 | FFD4 | 212 |
| EB. DRIV.SHRT. | MC is opened, EB is applied, Traction/Pump is disabled | Stand-by, running | Traction/Pump Request | 40 | 3222 | 254 |
| WRONG SET BAT. | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Adjust the SET BATTERY parameter in the ADJUSTMENT menu | 41 | 3100 | 251 |

| Error code | Effect | Condition | Restart procedure | MDI / LED CODE | CAN OPEN CODE | ZAPI CODE |
|---|---|---|---|---|---|---|
| WRONG KEY VOLT. | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Adjust the SET BATTERY parameter in the ADJUSTMENT menu | 41 | 3101 | 170 |
| EB. DRIV.OPEN | MC is opened, EB is applied (the command is released), traction is disabled | Running | Traction Request | 42 | 3224 | 246 |
| EB. COIL OPEN | MC remains closed, EB is applied (the command is released), traction is disabled | Start-up, Stand-by, running | Traction Request | 43 | FFD8 | 216 |
| WAIT MOTOR STILL | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Key re-cycle | 45 | FF9B | 155 |
| HANDBRAKE | Traction/Pump is disabled | Start-up, stand-by, running | Traction/Pump request | 46 | FFDD | 221 |
| MOT.PHASE SH. | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Traction/Pump request | 47 | FFC4 | 196 |
| THROTTLE PROG. | MC remains closed, EB is applied, traction disabled and a warning is shown in the display. | Start-up, Stand-by, running | Traction/Pump Request | 48 | FFF3 | 243 |
| LIFT+LOWER | Pump is stopped | Start-up, stand-by, running | Pump request | 49 | FFBB | 187 |
| TILLER OPEN | MC opens | Start-up, stand-by, running | Close the tiller input A1/A11. | 51 | 0000 | 228 |
| STBY I HIGH | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up, stand-by | Traction/Pump request | 53 | 2311 | 53 |
| OVERLOAD | MC is opened, EB is applied, Traction/Pump is disabled | Running | Traction/Pump request | 57 | FFB4 | 180 |
| SLAVE MOT ALARM | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up, stand-by, running | Key re-cycle | 59 | FF89 | 137 |
| CAPACITOR CHARGE | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Traction/Pump request | 60 | 3130 | 60 |
| BACK EMF HIGH | The maximum traction speed is limited and a warning message is shown in the display | Running | Key re-cycle | 60 | FF8A | 138 |
| THERMIC SENS. 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 | | 61 | 4211 | 250 |
| 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 disabled | Start-up, stand-by, running | Traction/Pump Request | 63 | FFCC | 204 |
| TILLER ERROR | Traction is disabled, EB applied | Stand-by, running | Traction/Pump or valves request | 64 | FFB9 | 185 |
| MOTOR TEMPERAT. | Maximum current is linearly reduced (see paragraph 9.17) and speed is reduced to a fixed value. | Start-up, stand-by, running | Wait for the motor to cool down | 65 | 4110 | 65 |
| MOTOR TEMP. STOP | EB is applied, Traction/Pump and valves are disabled | Start-up, stand-by, running | Wait for the motor to cool down | 65 | FFB2 | 178 |
| NO CAN MSG DISP | Economy mode is activated. | Start-up, stand-by, running | | 66 | FF96 | 150 |
| NO CAN MSG. XX | MC is opened, EB is applied, Traction/Pump and valves are disabled | Start-up, stand-by, running | Traction/Pump or valves 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 and valves are disabled | Start-up | Key re-cycle | 69 | 3302 | 193 |

| Error code | Effect | Condition | Restart procedure | MDI / LED CODE | CAN OPEN CODE | ZAPI CODE |
|---|---|---|---|---|---|---|
| EPS RELAY OPEN | EB is applied, Traction/Pump and valves are disabled | Start-up, stand-by, Running | Traction/Pump or valves request | 70 | FFCD | 205 |
| WRONG RAM MEM. | MC is opened, EB is applied, Traction/Pump and valves are disabled | Stand-by | Key re-cycle | 71 | FFD2 | 210 |
| STO-SS1 ALARM XX | MC is opened, EB is applied, Traction/Pump is disabled | Running | Alarm reset input and new traction request | **72** | **FF8E** | **142** |
| STO-SS1 ACTIVE XX | A warning is shown in the display | Running | | **72** | **FF8D** | **141** |
| DRIVER SHORTED | MC is opened (the command is released), EB is applied, Traction/Pump and valves are disabled | 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 and valves are disabled | Start-up, stand-by, running | Valves or Traction/Pump request | 75 | 3221 | 75 |
| COIL SHOR. EB. | MC is opened, EB is applied, Traction is disabled. | Start-up, stand-by, running | Traction request | 76 | FFB1 | 177 |
| COIL SHOR. MC | MC is opened, EB is applied, Traction/Pump and valves are disabled | Start-up, stand-by, running | Valves or Traction/Pump request | 76 | 2250 | 223 |
| VDC LINK OVERV. | MC is opened, EB is applied, Traction/Pump and valves are disabled | Stand-by, running | Valves or Traction/Pump request | 77 | FFCA | 202 |
| VACC NOT OK | Traction/Pump motor is disabled | Start-up, stand-by, running | Accelerator at rest | 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 disabled | Start-up, stand-by | Traction request | 79 | FF4F | 79 |
| FORW + BACK | Traction is disabled | Start-up, stand-by, running | Traction request | 80 | FF50 | 80 |
| POT MISMATCH | Traction/Pump motor is disabled | Start-up, stand-by, running | Accelerator at rest | 78 | FF97 | 151 |
| AGV | Traction is disabled | Start-up, stand-by, running | Traction request | 80 | FF9A | 154 |
| SPEED OVERHEAD | MC is opened , EB is applied, traction/pump and valves are disabled | Running | Traction request | 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 is applied, Traction/Pump and valves are disabled | Start-up | Key re-cycle | 83 | FF51 | 181 |
| POS. EB. SHORTED | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Key re-cycle | 84 | 3223 | 195 |
| POS.EB.SHORT PIN | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Key re-cycle | 84 | FFA2 | 162 |
| POS.EB.SHORT GND | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Key re-cycle | 84 | FFA4 | 164 |
| VACC OUT RANGE | Traction/Pump motor is stopped | Start-up, Stand-by, Running | potentiometer acquisition procedure | 85 | FFE2 | 226 |
| PEDAL WIRE KO | Traction is stopped | Start-up, Stand-by, Running | Traction request | 86 | FF56 | 86 |

| Error code | Effect | Condition | Restart procedure | MDI / LED CODE | CAN OPEN CODE | ZAPI CODE |
|---|---|---|---|---|---|---|
| SAFETY DIAG. XX | MC is opened, EB is applied, Traction/Pump and valves are disabled | Start-up, standby, running | Key re-cycle | **87** | FF92 | **146** |
| SAFETY SW. XX | MC is opened, EB is applied, Traction/Pump and valves are disabled | Start-up, standby, running | Key re-cycle | **87** | FF91 | **145** |
| SAFETY INIT. XX | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Key re-cycle | **87** | **FF8F** | **143** |
| 1175 NOT ACTIVE | A warning is shown in the display. Traction/Pump and valves are enabled. | Start-up | Check SAFETY LEVEL and CONTROLLER TYPE parameters. Key re-cycle | **87** | **FF8C** | **140** |
| VDC OFF SHORTED | MC is opened, EB is applied, Traction/Pump and valves are disabled | Start-up, Stand-by, Running | Key re-cycle | 88 | FFC8 | 200 |
| POWERMOS SHORTED | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Key re-cycle | 89 | FFE9 | 233 |
| WRONG SLAVE VER. | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Key re-cycle | 91 | FFC5 | 197 |
| CURRENT GAIN | Controller works, but with low maximum current | Start-up, stand-by | Current calibration | 92 | 6302 | 236 |
| PARAM TRANSFER | MC stays closed, EB is applied, Traction/Pump and valves are disabled | Start-up, stand-by, running | | 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 and valves are disabled | Stand-by, running | Key re-cycle | 96 | FFFA | 237 |
| M/S PAR CHK MISM | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Load again the parameters and Key re-cycle | 97 | FFC6 | 198 |
| CURRENT PROFILE | EB is applied, Traction/Pump is disabled | Start-up, stand-by | Check the current profile and Traction/Pump request | 98 | FFC9 | 201 |

### 10.3.1 Troubleshooting of alarms from master MCU

**1175 NOT ACTIVE**

Cause:

This alarm warns the user that the CONTROLLER TYPE selected does not support the SAFETY LEVEL 4.

Troubleshooting:

Ask for assistance to a Zapi technician.

**ACQUIRE ABORT**

Cause:

The acquiring procedure relative to the absolute feedback sensor failed.

**ACQUIRE END**

Cause:

The absolute feedback sensor has been successfully acquired.

**ACQUIRING A.S.**

Cause:

Controller is acquiring data from the absolute feedback sensor.

Troubleshooting:
The alarm ends as soon as the acquisition is done.

**AGV**
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**
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 key re-cycle does not solve the problem, it is necessary to replace the logic board.

**AUX BATT. SHORT.**
Cause:
The voltage on PEB output A2 (A19) is at high value even if it should not.
The parameter POSITIVE E.B. has to be set in accordance with the hardware configuration (see paragraph 3.2), because the software makes a proper diagnosis depending on the parameter POSITIVE E.B.; a wrong setting could generate a false fault. This alarm can only appear if POSITIVE E.B. is set to 1 (PEB from TILLER/SEAT).

Troubleshooting:
Verify that the parameter POSITIVE E.B. is set in accordance with the actual coil positive supply (see paragraph 8.2.5).
If the POSITIVE E.B. value is correct then the problem is in the controller, which has to be replaced.

**BACK EMF HIGH**
Cause:
When MOTOR TYPE, under the SPECIAL ADJUST. list, is set to BL MOTOR, the maximum traction speed is imposed by the motor speed constant; high back EMF values may damage the inverter. While motoring, if the traction speed exceeds the speed limit imposed by the motor speed constant, the software limits the motor speed and rises the alarm BACK EMF HIGH.

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

**BATTERY LOW**
Cause:

The parameter BATTERY CHECK is other than 0 (SET OPTION list, paragraph 8.2.2) and the 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**
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.

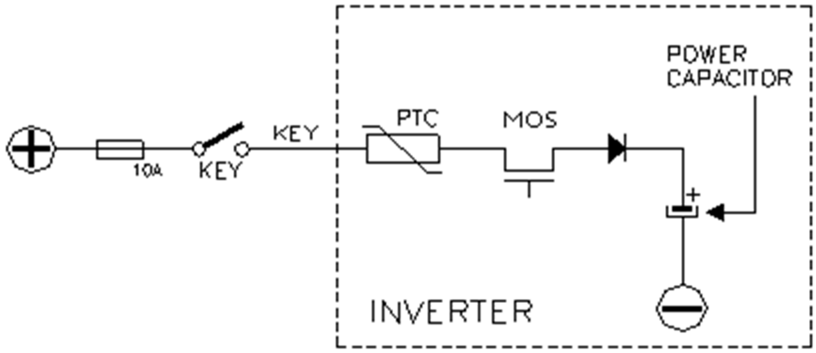
**BMS NOT READY**
Cause:
This alarm occurs if the BMS FUNCTION is enabled and the controller does not receive any information about the battery state of charge; the battery management system is not operative.

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

**BRAKE RUN OUT**
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**
Cause
When the key is switched on, the inverter charges the power capacitor bank through a dedicated pre-charge circuit and monitors the evolution of the capacitors voltage. The charging current is limited by a PTC. After a fixed timeout, if the capacitor bank voltage results less than a certain percentage of the key voltage then the alarm is raised and the main contactor is not closed.




Troubleshooting

Check if a lamp, a DC/DC converter, a fan or an auxiliary load is placed in parallel to the capacitor bank. External loads connected in parallel to the capacitor bank sink current from the pre-charge circuit preventing the capacitors from charging in the predefined time.

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**

Cause:

This message warns that it is time for the programmed maintenance.

Troubleshooting:

After executing the maintenance service, turn on the CHECK UP DONE option.

**COIL SHOR. EB.**

Cause:

This alarm occurs when there is an overload on the electromechanical brake driver; output pin NEB A4 (A2).

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.

**COIL SHOR. EVAUX**

Cause:

This alarm occurs when there is an overload on any of the auxiliary voltage-controlled outputs: NEV1 A9, NEV2 A11, NEV3 A33 (A23), NEV4 A34, NEV5 A8, and HORN A26.

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.

**COIL SHOR. MC**

Cause:

This alarm occurs when there is an overload on the main contactor driver; output pin NLC A12 (A16).

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.

**CONT. DRV. EV XX**

Cause:

One or more 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**

Cause

Before driving the MC coil, the controller checks if the contactor is stuck. The controller drives the power bridge for several dozens of milliseconds, trying to discharge the capacitor bank. If the capacitors voltage does not decrease below a certain percentage of the key voltage then the alarm is raised.

Troubleshooting

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

**CONTACTOR DRIVER**

Cause

The MC coil driver is not able to drive the load. The MC driver circuit is damaged.

Troubleshooting

Replace the logic board.

**CONTACTOR OPEN**

Cause

The MC 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

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

**CONTROLLER MISM.**

Cause

The software is not compatible with the hardware. Each controller produced is "signed" 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.

**CURRENT GAIN**
Cause:
The current gain parameters are at the default values. 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**
Cause:
The current profile parameters are wrong. Points P0 through P3 are expected to describe a descending profile. See paragraphs 8.2.8 and 9.15.

Troubleshooting:
Check the values under the CURRENT PROFILE list.

**DATA ACQUISITION**
Cause:
The controller is in calibration state.

Troubleshooting:
The alarm ends when the acquisition is completed.

**DRIVER SHORTED**
Cause
The driver of the MC coil is shorted.

Troubleshooting
Check if there is a short or an external low impedance path between NLC A12 (A16) and -B.
The driver circuit is damaged; replace the logic board.

**DRV. SHOR. EV XX**
Cause:
One or more valve drivers are shorted. For the meaning of code "XX", refer to paragraph 10.5.

Troubleshooting:
Check if there is a short circuit or an external 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**
Cause:
An open-load condition is detected on the electromechanical brake output NEB A4 (A2).

Troubleshooting:
Check the EB coil.
Check the wiring.

Check the EB positive terminal.
If the problem is not solved, replace the logic board.

**EB. DRIV.OPEN**
Cause:
The EB driver is not able to drive the load.

Troubleshooting:
Key re-cycle. If the problem is not solved, replace the logic board.

**EB. DRIV.SHRT.**
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 an external low impedance path between the negative coil terminal A4 (A2) and -B.
Check if the voltage applied is in accordance with the settings of the EB-related parameters (see paragraph 8.2.3).
If the problem is not solved, replace the controller.

**ED SLIP MISMATCH**
Cause:
A wrong set of the motor control parameters may cause this alarm.

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

**EEPROM KO**
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 the truck is forced to work with the default parameters set.

Troubleshooting:
Execute a CLEAR EEPROM procedure (refer to the Console manual) then switch the key off and on again. If the alarm pop up again, it is necessary to replace the controller. If the alarm disappears, please, note that after the CLEAR EEPROM operation the default parameters are loaded in the controller and thus it might be necessary to restore the application parameters.

**EMERGENCY**
Cause:
This alarm occurs when the EMERGENCY INPUT parameter 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**
Cause:
The controller receives from EPS information about the safety contacts being open.

Troubleshooting:
Verify the EPS functionality.

**EVP COIL OPEN**
Cause:
An open-load condition is detected on the proportional valve output NEVP1 A24 (A1).

Troubleshooting:
Check the EVP1 coil.
Check the EVP1 wiring.
If the problem is not solved, replace the logic board.

**EVP2 COIL OPEN**
Cause:
An open-load condition is detected on the proportional valve output NEVP2 A23.

Troubleshooting:
Check the EVP2 coil.
Check the EVP2 wiring.
If the problem is not solved, replace the logic board.

**EVP DRIV. SHORT.**
Cause
The EVP1 driver (NEVP1 output A24 (A1)) is shorted to ground.
The microcontroller detects a mismatch between the valve set-point and the feedback of the EVP1 output.

Troubleshooting
Check if there is a short circuit or an external low-impedance conduction path between the NEVP1 output and -B.
Collect information about:

- the voltage applied across the EVP1 coil,
- the current flowing in the coil,
- the impedance 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.

**EVP2 DRIV. SHORT.**
The EVP2 driver (NEVP2 output A23) is shorted to ground.
The microcontroller detects a mismatch between the valve set-point and the feedback of the EVP2 output.

Troubleshooting
Check if there is a short circuit or an external low-impedance conduction path between the NEVP2 output and -B.
Collect information about:

- the voltage applied across the EVP2 coil,
- the current flowing in the coil,
- the impedance 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**

Cause:

The EVP1 driver (NEVP1 output, pin A24 (A1)) is not able to drive the EVP1 coil.

Troubleshooting:

Key re-cycle. If the problem is not solved, replace the logic board.

**EVP2 DRIVER OPEN**

Cause:

The EVP2 driver (NEVP2 output, pin A23) is not able to drive the EVP2 coil.

Troubleshooting:

Key re-cycle. If the problem is not solved, replace the logic board.

**EVP COIL SHORT.**

Cause:

This alarm occurs when there is an overload on the EVP1 driver (NEVP1 output, pin A24 (A1)).

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.

**EVP2 COIL SHORT.**

Cause:

This alarm occurs when there is an overload on the EVP2 driver (NEVP2 output, pin A23).

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.

**FIELD ORIENT. KO**

Cause

The error between the estimated d-axis current and the relative setpoint 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**

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**
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**
Cause:
At start-up, the hardware circuit dedicated to enable and disable the EB driver (output NEB, pin A4 (A2)) is found to be faulty. The hexadecimal value "XX" facilitates Zapi technicians debugging the problem.

Troubleshooting:
Key re-cycle. If the problem is not solved, replace the logic board.

**HW FAULT EV. XX**
Cause:
At start-up, 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:
Key re-cycle. If the problem is not solved, replace the logic board.

**HW FAULT MC. XX**
Cause:
At start-up, the hardware circuit dedicated to enable and disable the MC driver (output NLC, pin A12 (A16)) is found to be faulty. The hexadecimal value "XX" facilitates Zapi technicians debugging the problem.

Troubleshooting:
Key re-cycle. If the problem is not solved, replace the logic board.

**HW FAULT XX**
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
T Key re-cycle. If the problem is not solved, replace the logic board.

**INCORRECT START**
Cause:
Incorrect starting sequence. Possible reasons for this alarm are:
- A travel demand active at key-on.
- Tiller input active at key on.

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

**INIT VMN HIGH XX**

Cause

Before closing the MC, one or more motor-phase voltage are sensed to be higher than expected. A short circuit or a low-impedance path to the +B 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 is inside the controller; replace it.

**INIT VMN LOW XX**

Cause

Before closing the MC, one or more motor-phase 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**

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**

Cause

An open-load condition is detected on the main contactor valve output NLC A12 (A16).

Troubleshooting
Check the MC coil.
Check the wiring.
Check the MC positive terminal.
If the alarm is still present, replace the logic board.

**LIFT+LOWER**
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**
Cause
The controller detects an under-voltage condition at the KEY input A10 (A8). Under-voltage threshold is:

| **Nominal voltage** | **24 V, 36 V, 48 V** | **72 V, 80 V** |
|---|---|---|
| Under-voltage threshold | **11 V** | **30 V** |

Troubleshooting (fault at startup or in standby)
Fault can be caused by a voltage drop on the key input signal due to a faulty key switch or 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 key input 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 and layout.

**LOGIC FAILURE #2**
Cause
Fault in the hardware section of the logic board which deals with voltage feedbacks of motor phases.

Troubleshooting
Key re-cycle. If the problem is not solved, replace the logic board.

**LOGIC FAILURE #3**
Cause
An overcurrent condition has been triggered while the power bridge was not driven.

Troubleshooting
Key re-cycle. If the problem is not solved, replace the controller.

**M/S PAR CHK MISM**
Cause:

At start-up, there is a mismatch in the parameter checksum between the master and the supervisor microcontrollers.

Troubleshooting:
Restore the parameters list.

**MOT.PHASE SH. XX**
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 phase connections on the motor side.
Verify the motor phase connections on the inverter side.
Replace the controller.
If the alarm does not disappear, the problem is in the motor; replace it.

**MOTOR TEMPERAT.**
Cause:
This warning occurs when the motor temperature sensor is open (if digital) or if the motor temperature exceeds the threshold defined by MAX. MOTOR TEMP. (if analog). See paragraph 8.2.3.

Troubleshooting:
Check the motor temperature reading in the TESTER function.
Check the sensor resistance and the sensor wiring.
If the sensor is fine, improve the cooling of the motor.
If the warning is present when the motor is cool, replace the controller.

**MOTOR TEMP. STOP**
Cause:
This warning occurs when the motor temperature sensor is open (if digital) or if the motor temperature exceeds the threshold defined by STOP MOTOR TEMP. (if analog). See paragraph 8.2.3.

Troubleshooting:
Check the motor temperature reading in the TESTER function.
Check the sensor resistance and the sensor wiring.
If the sensor is fine, improve the cooling of the motor.
If the warning is present when the motor is cool, replace the controller.

**NO CAN MSG DISP**
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**

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.**
Cause:
It is necessary to acquire the offset angle between the stator and the speed sensor, i.e. their relative angular offset.

Troubleshooting:
Perform the absolute position sensor automatic acquisition procedure. See paragraph 7.2.1.

**OPEN COIL EV. XX**
Cause:
An open-load condition is detected on one or more EV outputs NEV1 A9, NEV2 A11, NEV3 A33 (A23), NEV4 A34, NEV5 A8, and HORN A26. 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**
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 due to wrong adjustments of motor parameters.

**PARAM RESTORE**
Cause:
The controller has restored the default settings. If a CLEAR EEPROM was made before the last key re-cycle, this warning informs you that EEPROM was correctly cleared.

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

**PARAM TRANSFER**
Cause:
Master MCU is transferring parameters to the supervisor.

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

**PEDAL WIRE KO**
Cause:
A fault is detected in the accelerator unit.

Troubleshooting:
Check the pedal connection.
If the problem is not solved it is necessary to replace the logic board.

**PEV NOT OK**
Cause:
Terminal PEV A3 (A1) is floating or the voltage at this pin is different from that defined by parameter SET POSITIVE PEB (see the ADJUSTMENTS list, paragraph 8.2.3). This alarm can occur if one output among EVP1, EVP2, EV1, EV2, EV3, EV4, EV5, and HORN is present or if AUX OUT FUNCTION is active.

Troubleshooting:
Check the PEV terminal A3 (A1): it must be connected to the battery voltage downstream of the main contactor.
Set the nominal PEB A2 (A19) voltage in parameter SET POSITIVE PEB in the ADJUSTMENTS list (see paragraph 8.2.3).

**POS. EB. SHORT GND**
Cause:
The voltage on terminal PEB A2 (A19) is sensed lower than expected after the smart driver is driven ON.

Troubleshooting:
Verify that the parameter POSITIVE E.B. is set in accordance with the actual EB coil positive supply (see paragraph 8.2.5).
Check if there is an external short or an external low impedance path between PEB A2 (A19) and any ground reference (-B or GND).
If the issue is not resolved, the problem is in the controller; replace the logic board.

**POS. EB. SHORT PIN**
Cause:
The voltage on terminal PEB A2 (A19) is sensed higher than expected with the smart driver OFF.

Troubleshooting:
Verify that the parameter POSITIVE E.B. is set in accordance with the actual coil positive supply (see paragraph 8.2.5).
Check if there is an external short or an external low impedance path between PEB A2 (A19) and the positive battery terminal +B or key input.
If the issue is not resolved, the problem is in the controller; replace the logic board.

**POS. EB. SHORTED**
Cause:
The voltage on terminal PEB A2 (A19) is sensed higher than expected with the smart driver OFF.

Troubleshooting:
Verify that the parameter POSITIVE E.B. is set in accordance with the actual coil positive supply (see paragraph 8.2.5).
Check if there is an external short or an external low impedance path between PEB A2 (A19) and the positive battery terminal +B or key input.

If the issue is not resolved, the problem is in the controller; replace the logic board.

**POSITIVE LC OPEN**

Cause:

The voltage feedback of the MC output driver, pin A12 (A16), is different than expected.

Troubleshooting:

Verify that the MC coil is properly connected.
Verify that the CONF. POSITIVE LC parameter is set in accordance with the actual coil positive supply (see paragraph 8.2.5). Software makes a proper diagnosis depending on the parameter; a wrong setting could generate a false fault.
In case no failures/problems have been found, the problem is in the controller; replace the logic board.

**POT MISMATCH**

Cause:

This alarm may occur only if the auxiliary potentiometer is of type crossed-twin in combination with the main potentiometer (see parameter AUX.POT. TYPE under the SET OPTIONS list, paragraph 8.2.2) and the controller type is set to standard traction or standard pump or master traction. 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**

Cause

The error between the power setpoint 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**

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**

Cause:

The speed of the hybrid generation set exceeded the maximum one.

**SAFETY DIAG. XX**

Cause
One of the safety related diagnosis has failed. The hexadecimal value "XX" helps Zapi technicians debugging the problem.

Troubleshooting
The fault condition could be due to wrong adjustments of the safety related parameters. Ask for assistance to a Zapi technician.
Using the TESTER function, verify the state of the STO and SS1 safety inputs.
Check the STO and SS1 connections.
In case the problem is not solved, replace the logic board.

**SAFETY INIT. XX**
Cause
One of the safety related modules has reported an error during its initialization. The hexadecimal value "XX" helps Zapi technicians to identify which module has failed.

Troubleshooting
The fault condition could be due to wrong adjustments of the safety related parameters. Ask for assistance to a Zapi technician.
Using the TESTER function, verify the state of the STO and SS1 safety inputs.
Check the STO and SS1 connections.
In case the problem is not solved, replace the logic board.

**SAFETY SW. XX**
Cause
One of the safety related modules has reported an error. The hexadecimal value "XX" helps Zapi technicians to identify which module has failed.

Troubleshooting
The fault condition could be due to wrong adjustments of the safety related parameters. Ask for assistance to a Zapi technician.
Using the TESTER function, verify the state of the STO and SS1 safety inputs.
Check the STO and SS1 connections.
In case the problem is not solved, replace the logic board.

**SEAT MISMATCH**
Cause
This alarm can appear only in a traction + pump configuration or in a multi-motor configuration.
A mismatch is detected between the TILLER/SEAT input of the traction controller and the TILLER/SEAT input of the pump controller.

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 logic board.

**SENS MOT TEMP KO**
Cause:
The output of the motor thermal sensor is out of range.

Troubleshooting:
Check the SET MOT.TEMPERAT parameter value in the SET OPTIONS list; it must be set in agreement with the thermal sensor installed.

Measure the resistance of the motor thermal sensor and check it against the expected value.
Check the wiring.
If the problem is not solved, replace the logic board.

**SMARTDRIVER KO**

Cause:

Hardware problem in the smart driver circuit. The driver is turned ON but the output voltage at pin PEB A2 (A19) does not increase.

Troubleshooting:

Verify that the EB coil is connected correctly between terminals PEB A2 (A19) and NEB (pin A4) (A2); the output of the smart driver circuit is evaluated through 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 this parameter; a wrong setting could generate a false fault.
If the issue is not solved, replace the logic board.

**SPEED FB.ERR. XY**

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 MCU) |
| 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 electrical and the mechanical functionality of the sensor.
Check the sensor wiring.
Check the mechanical installation of the sensor; the issue may be it slips inside its housing.
Verify the cable laying and measure the feedback sensor signal distortion. The electromagnetic noise coupled with the sensor or with the sensor signals can be source of problems.
For generic errors 1 through 4, contact a Zapi technician for assistance.
Try to replace the sensor. If the problem is still present after replacing the sensor, the controller has to be replaced.

**SPEED OVERHEAD**
Cause:
The motor speed has exceeded the TOP MAX SPEED value (in the HARDWARE SETTINGS list) by more than a 100 Hz difference.

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

**STALL ROTOR**
Cause:
The motor rotor is stuck or the encoder signal is not correctly received by the controller.

Troubleshooting:
Check the encoder status.
Check the encoder 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; to achieve this condition and solve the STALL ROTOR issue, it may be necessary to adjust the ROTATION CW MOT and ROTATION CW ENC or ROTATION CW POS parameters in the FEEDBACK SENSOR list.
If the problem is not solved, replace the logic board.

**STBY I HIGH**
Cause
In standby, the measured phase current value is different from zero.

Troubleshooting
The current sensor or the current feedback circuit is damaged. Replace the logic board.

**STEER SENSOR KO**
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 ALARM XX**
Cause
The STO or SS1 procedure has reported an alarm. The hexadecimal value “XX” facilitates Zapi technicians to identify 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.

**STO-SS1 ACTIVE XX**

Cause

The STO or SS1 procedure is in progress. The hexadecimal value “XX” identifies which procedure is undergoing.

Troubleshooting

Wait until the STO procedure or SS1 procedure or both are done.

**TH. PROTECTION**

Cause:

The temperature of the controller power section is above 85 °C.
The maximum current is linearly decreased with the temperature excess from 85 °C up to 105 °C. At 105 °C the current is limited to 0 A.

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 anchoring the controller base plate to 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 this case it is necessary to replace the controller.

**THERMIC SENS. KO**

Cause:

The output of the controller thermal sensor is out of range.

Troubleshooting:

Replace the controller.

**THROTTLE PROG.**

Cause:

A wrong profile has been set in the throttle profile.

Troubleshooting:

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

**TILLER ERROR**

Cause:

Input mismatch between the H&S input (pin A6) and the TILLER/SEAT input (pin A1): the two inputs are activated at the same time.

Troubleshooting:

Check if there are wrong connections in the external wiring.
Using the TESTER function of the controller verify that the H&S and TILLER inputs readings are in accordance with the actual state of the external input switches.
Check if there is a short circuit between pins A6 and A1.
In case no failures/problems have been found, the logic board has to be replaced.

**TILLER OPEN**

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 tiller microswitch.
If the problem is not solved, replace the logic board.

**VACC NOT OK**
Cause:
This alarm occurs upon a travel request if the accelerator set point is above the minimum value acquired during 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**
Cause:
The CPOT input read by the microcontroller is not within the MIN VACC ÷ MAX VACC range, programmed through the PROGRAMM VACC function (see paragraph 9.1).
The acquired values MIN VACC and MAX VACC are inconsistent.

Troubleshooting:
Acquire the maximum and minimum potentiometer values through 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.**
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** | **72 V / 80 V** |
|---|---|---|---|
| Overvoltage threshold | 35 V | 72.5 V | 115 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; the MCU discerns between these two conditions evaluating the voltage of the 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 and the battery power cable connection.
Check if there are voltage drops on the key input A10 (A8).

**VDC OFF SHORTED**

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 the allowed range replace the battery.
Check the key voltage and the key wiring.
If the battery voltage is ok then replace the logic board.

**VKEY OFF SHORTED**
Cause:
The logic board measures a key voltage value that is constantly under the minimum value allowed.

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

**VMN HIGH**
Cause 1
At start-up, the software checks the power bridge; if 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 then this alarm occurs.

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 diagnosis has succeeded but after the MC has been closed one of the phase voltages is sensed to be higher than half the battery voltage.

Troubleshooting 2:
Check the motor internal connections.
Check the motor power cables.
If the issue is not solved, replace the controller.

**VMN LOW**
Cause 1
At start-up, the software checks the power bridge; if 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 then this alarm occurs.

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

Cause 2
At start-up the diagnosis has succeeded but after the MC has been closed, while the controller is in standby, one of the phase voltages is sensed to be lower than expected.

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

**WAIT MOTOR STILL**
Cause:
The controller is waiting for the motor to stop rotating. This warning can only appear in BLEX NEW GENERATION for brushless motors.

**WAITING FOR NODE**
Cause:
The controller receives from the CAN bus the message that another controller in the CAN network is in fault condition; as a consequence the controller itself cannot enter into an operative status, but it has to wait until the faulty node becomes operative.

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

**WARNING SLAVE**
Cause:
Warning on supervisor MCU.

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

**WATCHDOG**
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 issue which drops the internal master-supervisor communication.

**WRONG FBSENS. SET**
Cause
Mismatch between “ENCODER PULSES 1” parameter and “ENCODER PULSES 2” parameter (see paragraph 8.2.7).

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

**WRONG KEY VOLT.**
Cause
At startup the controller monitors the key voltage and it verifies that it is within the range defined by parameters VOLTAGE THR LOW and VOLTAGE THR HIGH (ADJUSTMENT list) 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 the ADJUSTMENTS list matches with the battery nominal voltage.
Measure the battery voltage with a voltmeter and check that it matches the nominal battery voltage ± a range defined by the parameters VOLTAGE THR LOW and VOLTAGE THR HIGH, otherwise replace the battery.
If the battery nominal voltage is not available for the SET BATTERY parameter inside the ADJUSTMENTS list then check the HW BATTERY RANGE value in the SPECIAL ADJUST. list and contact a Zapi technician.
Through the TESTER function, check that the KEY VOLTAGE reading shows the same value as the voltage measured with a voltmeter on the key input pin A10 (A8). If it does not match, then modify the ADJUST KEY VOLT. parameter under the ADJUSTMENTS list according to the value read by the voltmeter.
Check the wiring.
In case the problem is not solved, replace the logic board.

**WRONG PERFORM.**

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 performance mode and the power mode results the highest performance mode. Contact a Zapi technician for assistance.

**WRONG RAM MEM.**

Cause

The SW algorithm that checks the main RAM finds corrupted registers. 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.

**WRONG SET BAT.**

Cause

At start-up, after closing the main contactor, the controller monitors the battery voltage at the +B post and it verifies that it is within the range defined by the 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 in the ADJUSTMENTS list matches with the battery nominal voltage.
Measure the battery voltage with a voltmeter and check that it matches the nominal battery voltage ± a range defined by the parameters VOLTAGE THR LOW and VOLTAGE THR HIGH, otherwise replace the battery.
If the battery nominal voltage is not available for the SET BATTERY parameter under the ADJUSTMENTS list then check the HW BATTERY RANGE value in the SPECIAL ADJUST. list and contact a Zapi technician.

Through 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 the ADJUSTMENTS list according to the value read by the voltmeter.
In case the problem is not solved, replace the logic board.

**WRONG SLAVE VER.**
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 MCU

| Error Code | Effect | Condition | Restart procedure | MDI / LED CODE | CAN OPEN CODE | ZAPI CODE |
|---|---|---|---|---|---|---|
| SOFTWARE ERROR | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up, stand-by, running | Key re-cycle | 0 | FFE6 | 230 |
| SPEED FB.ERR. XX | MC is opened, EB is applied, Traction/Pump and valves are stopped | Running | Valves or Traction or DC pump request | 3 | FFA8 | 221 |
| WATCHDOG | MC is opened, EB is applied, traction/pump and valves are stopped | Stand-by, running | Key re-cycle | 8 | 6010 | 8 |
| CONTROLLER MISM. | MC is not closed, EB is applied, Traction/Pump and valves are 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 is applied, traction/pump and valves are stopped | Running | Key re-cycle | 15 | FFF2 | 242 |
| OUT MISMATCH XX | MC is opened, EB is applied, traction/pump and valves are stopped | Running | Key re-cycle | 16 | FFE3 | 227 |
| LOGIC FAILURE #3 | MC is not closed, EB is applied, traction/pump and valves are disabled | Stand-by | Key re-cycle | 17 | FF11 | 17 |
| LOGIC FAILURE #1 | MC is opened, EB is applied, traction/pump and valves are stopped | Stand-by, running | Key re-cycle | 19 | 5114 | 19 |
| INPUT MISMATCH | MC is opened, EB is applied, Traction/Pump and valves are 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 DISP | Economy mode is activated. | Start-up, stand-by, running | | 66 | FFC5 | 196 |
| NO CAN MSG. | MC is opened, EB is applied, Traction/Pump and valves are disabled | Start-up, stand-by, running | Valves or Traction/Pump request | 67 | 8130 | 248 |
| NO CAN WR MSG.XX | No effect | Start-up, stand-by, running | | 67 | 8131 | 229 |
| WRONG RAM MEM. | MC is opened, EB is applied, Traction/Pump and valves are disabled | Stand-by | Key re-cycle | 71 | FFD2 | 210 |
| VDC LINK OVERV. | MC is opened, EB is applied, Traction/Pump and valves are stopped | Stand-by, running | Valves or Traction/Pump request | 77 | FFCA | 202 |
| WRONG FBSENS.SET | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Key re-cycle | 85 | FF51 | 201 |

| Error Code | Effect | Condition | Restart procedure | MDI / LED CODE | CAN OPEN CODE | ZAPI CODE |
|---|---|---|---|---|---|---|
| STEER SENSOR KO | EB is applied, traction/pump stopped | Start-up, stand-by, running | Key re-cycle | 95 | FFC3 | 200 |
| ANALOG INPUT | MC is opened, EB is applied, traction/pump and valves are stopped | Stand-by, running | Key re-cycle | 96 | FFFA | 237 |
| STO-SS1 ALARM XX | MC is opened, EB is applied, traction/pump and valves are disabled | Start-up, standby, running | Key re-cycle | 97 | FFF3 | 199 |
| SAFETY DIAG. XX | MC is opened, EB is applied, traction/pump and valves are stopped | Start-up, stand-by, running | Key re-cycle | 98 | FFF4 | 195 |
| SAFETY SW. XX | MC is opened, EB is applied, traction/pump and valves are stopped | Start-up, stand-by, running | Key re-cycle | 98 | FFF5 | 194 |
| SAFETY INIT. XX | MC is not closed, EB is applied, Traction/Pump and valves are disabled | Start-up | Key re-cycle | 98 | FFF7 | 192 |

### 10.4.1 Troubleshooting of alarms from supervisor MCU

**ANALOG INPUT**

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 key re-cycle does not solve the problem, it is necessary to replace the logic board.

**CONTROLLER MISM.**

Cause:

The software is not compatible with the hardware. Each controller produced is "signed" 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**

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 the truck is forced to work with the default parameters set.

Troubleshooting:

Execute a CLEAR EEPROM procedure (refer to the Console manual) then switch the key off and on again. If the alarm occurs permanently, it is necessary to replace the controller. If the alarm disappears, please, note that after the CLEAR EEPROM operation the default parameters are loaded in the controller and thus it might be necessary to restore the application parameters.

**INPUT MISMATCH XX**

Cause:

The supervisor microcontroller records different input values with respect to the master microcontroller. The hexadecimal value “XX” facilitates Zapi technicians debugging the problem; it identifies the input signals causing the alarm.

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**

Cause

The controller detects an under-voltage condition at the KEY input A10 (A8). Under-voltage threshold is:

| **Nominal voltage** | **24 V, 36V, 48 V** | **72V, 80 V** |
|---|---|---|
| Under-voltage threshold | **11 V** | **30 V** |

Troubleshooting (fault at startup or in standby)

Fault can be caused by a voltage drop on the key input signal due to a faulty key switch or 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 key input 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 and layout.

**LOGIC FAILURE #3**

Cause

An overcurrent condition has been triggered while the power bridge was not driven.

Troubleshooting

Key re-cycle. If the problem is not solved, replace the controller.

**NO CAN MSG DISP**

Cause

CAN bus communication with the display does not work properly. Upon this alarm, the economy mode is activated by default.

Troubleshooting

Verify the CAN bus network and the display connected to it.
With 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**

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.
With a multimeter check the impedance between CANH and CANL; it shall be 60 Ω. If the alarm persists, replace the logic board.

**NO CAN WR MSG.XX**
Cause
CAN bus communication does not work properly. The hexadecimal value "XX" identifies the faulty node.

Troubleshooting
Verify the CAN bus network (external issue).
With a multimeter measure the impedance between CANH and CANL; it shall be 60 Ω. If the problem is not solved, replace the logic board (internal issue).

**OUT MISMATCH XX**
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 MCUs.
Ask for assistance to a Zapi technician.
If the problem is not solved, replace the logic board.

**PARAM RESTORE**
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 logic board.

**SAFETY DIAG. XX**
Cause
One of the safety related diagnosis has failed. The hexadecimal value "XX" helps Zapi technicians debugging the problem.

Troubleshooting
The fault condition could be due to wrong adjustments of the safety related parameters. Ask for assistance to a Zapi technician.
Using the TESTER function, verify the state of the STO and SS1 safety inputs.
Check the STO and SS1 connections.
In case the problem is not solved, replace the logic board.

**SAFETY INIT. XX**
Cause
One of the safety related modules has reported an error during its initialization. The hexadecimal value "XX" helps Zapi technicians to identify which module has failed.

Troubleshooting
The fault condition could be due to wrong adjustments of the safety related parameters. Ask for assistance to a Zapi technician.
Using the TESTER function, verify the state of the STO and SS1 safety inputs.
Check the STO and SS1 connections.
In case the problem is not solved, replace the logic board.

**SAFETY SW. XX**
Cause
One of the safety related modules has reported an error. The hexadecimal value "XX" helps Zapi technicians to identify which module has failed.

Troubleshooting
The fault condition could be due to wrong adjustments of the safety related parameters. Ask for assistance to a Zapi technician.
Using the TESTER function, verify the state of the STO and SS1 safety inputs.
Check the STO and SS1 connections.
In case the problem is not solved, replace the logic board.

**SOFTWARE ERROR XX**
Cause
This alarm can occur only by setting DEBUG CANMESSAGE = 15 under SPECIAL ADJUSTMENTS (paragraph 8.2.4). The alarm returns the hexadecimal code relative to the fail of specific software portions. To be reported to Zapi technicians for dedicated debug of the software.

**SP MISMATCH XX**
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**
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 MCU) |
| 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 sensor wiring.
Check the mechanical installation of the sensor; the issue may be it slips inside its housing.
Verify the cable laying and measure the feedback sensor signal distortion. The electromagnetic noise coupled with the sensor or with the sensor signals can be source of problems.
For generic errors 1 through 4, contact a Zapi technician for assistance.
Try to replace the sensor. If the problem is still present after replacing the sensor, the controller has to be replaced.

**STEER SENSOR KO**
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 ALARM XX**
Cause
The STO or 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.**

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** | **72 V / 80 V** |
|---|---|---|---|
| Overvoltage threshold | 35 V | 72 V | 115 V |

As soon as the fault occurs, power bridge and MC are opened. The condition is triggered using the same HW interrupt as for under-voltage detection; the MCU discerns between these two conditions evaluating the voltage of the 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 and the battery power-cable connection.

**W.SET. TG-EB XX**

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.

Troubleshooting:

Ask for the assistance of a Zapi technician.

If the problem is not solved, replace the logic board.

**WATCHDOG**

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 issue which drops the internal master-supervisor communication.

**WRONG FBSENS.SET**

Cause:

Mismatch between “ENCODER PULSES 1” parameter and “ENCODER PULSES 2” parameter (see paragraph 8.2.7).

Troubleshooting

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

**WRONG RAM MEM.**

Cause:

The SW algorithm that checks the main RAM finds corrupted registers. 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 identifies the faulty EV.

EVs are coded with a decimal number:

- **01:** EV1, pin A9 (A7)
- **02:** EV2, pin A11
- **03:** EV3, pin A33 (A23)
- **04:** EV4, pin A34
- **05:** EV5, pin A8 (A6)
- **06:** EV6, pin A26

In case the same issue affects a number of EV outputs, only the higher number is shown.

# 11 RECOMMENDED SPARE PARTS

| Part number | Description | Versions |
|---|---|---|
| C12532 | AMPSEAL CONNECTOR 35 pins Female | Premium |
| C12531 | AMPSEAL CONNECTOR 23 pins Female | Standard |
| C16520 | 10A 20mm Control Circuit Fuse | All |
| C29508 | SW 180 24V single-pole contactor | 24V |
| C29522 | SW 180 48V single-pole contactor | 36/48V |
| C29553 | SW 150 80V single-pole contactor | 72/80V |
| C16603 | Protected 200 A strip UL fuse | 24V 240A |
| C16591 | Protected 175 A strip UL fuse | 24V 165A<br>24V 200A<br>36V/48V 180A |
| C16606 | Protected 125 A strip UL fuse | 36V/48V 140A<br>36V/48V 120A |
| C16629 | Protected 100 A strip UL fuse | 24V 100A<br>36V/48V 80A<br>72V/80V 120A |
| C16628 | Protected 50 A strip UL fuse | 72V/80V 80A |

# 12 PERIODIC MAINTENANCE

For the proper and safe operation of the systems where the Zapi controllers are employed, the Zapi controllers and the surrounding devices must undergo a periodic maintenance. This maintenance activity is aimed to verify the proper functionality of the inverter itself, the wear of the electrical contacts, micro-switches, battery and motor cables and connections, potentiometers, moving contacts, mechanical parts like pedals or tiller.

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 not conform to the information included in this manual.

During periodic checks, if a technician finds any situation that could cause damage or compromise the 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.***

# 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.

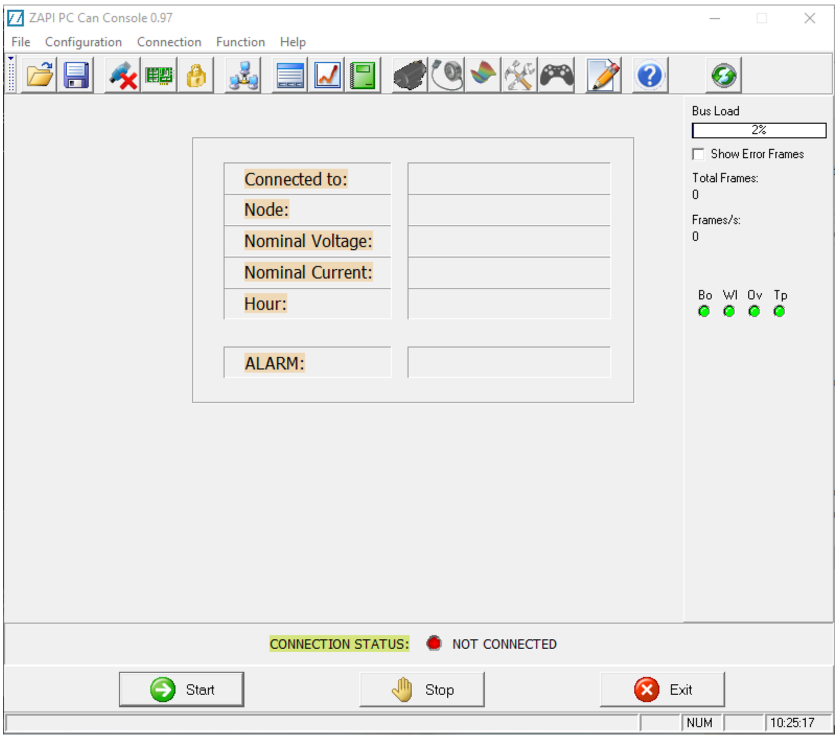
## 13.1 Appendix A: PC CAN Console

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

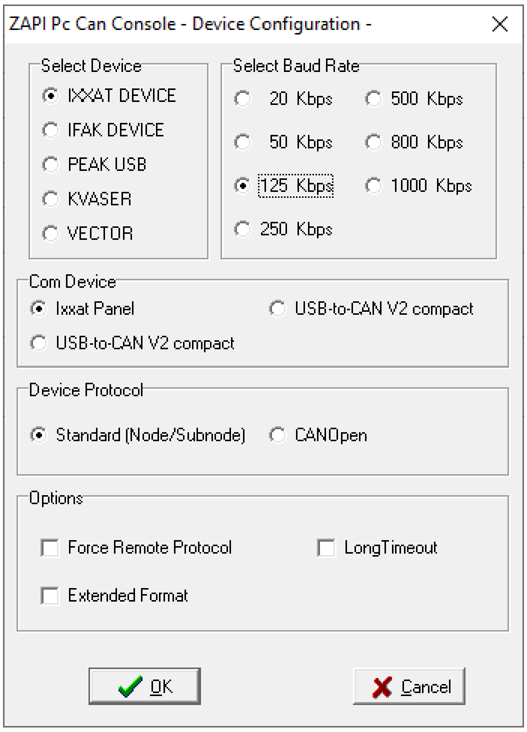
Running the PC Can Console software, the following window appears:




*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*

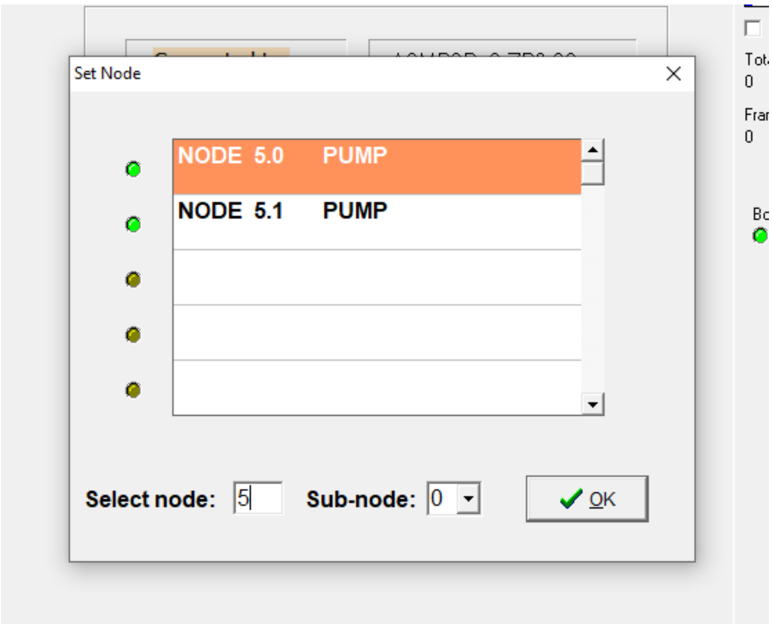
From this form you can define the CAN device in use (IXXAT, IFAK or Peak) and the communication speed.

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 operated 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 |
| CAN operated, multi-motor (master) | 3.0 | 3.1 | 12 (*) | 13 (*) |
| CAN operated, 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.

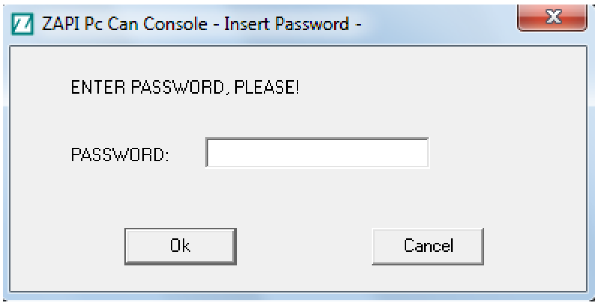



*ZAPI PC CAN Console: node selection.*

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 Start 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 a head line like the following.

AXMT2B 3 ZP0.56

Where:

AX: ACEX NEW GENERATION (BX: BLEX NEW GENERATION).
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:

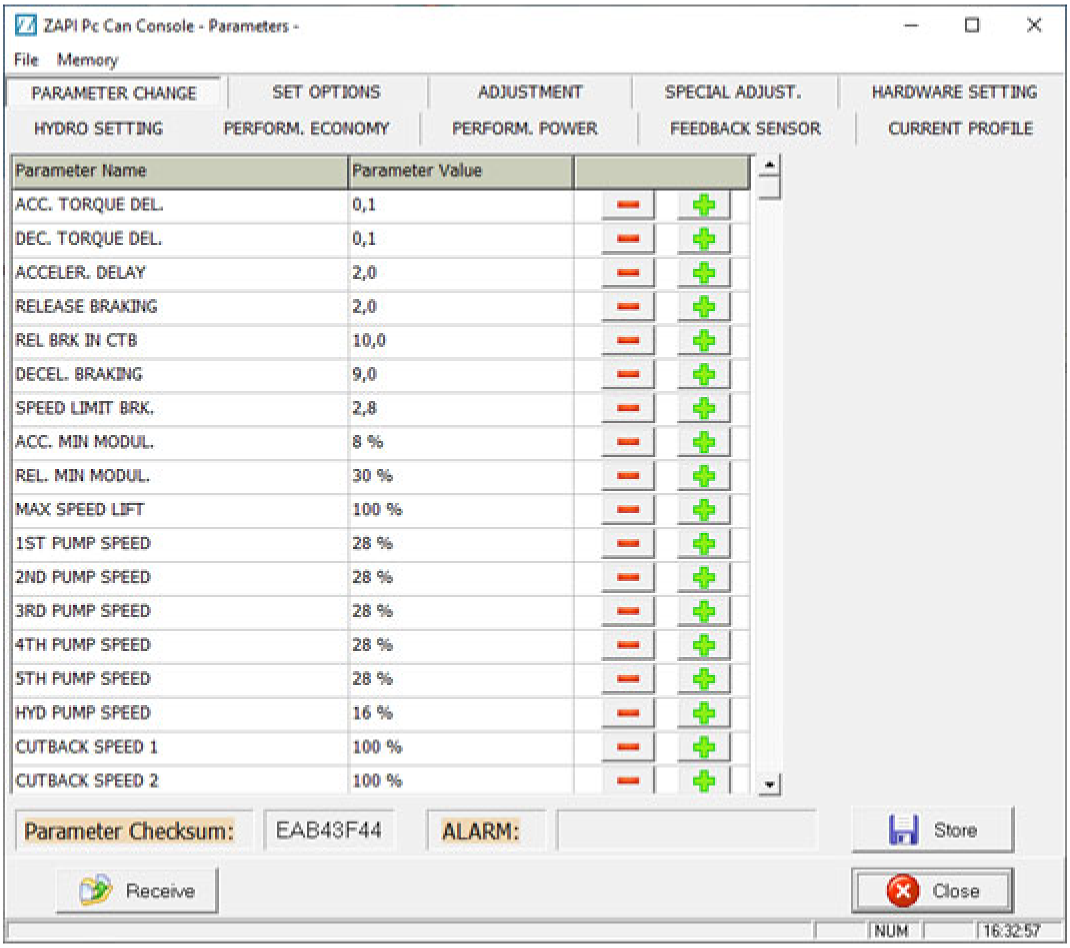
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Code: | A | B | C | D | E | G | H |
| Pulses/rev: | 32 | 64 | 80 | 128 | 177 | 256 | 512 |

| | | | | | |
|---|---|---|---|---|---|
| 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 Receive button to download on the Zapi Can Console all the Zapi controller parameters configuration.

If the password inserted is right, 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 one sample of controller to another one.

Moreover, parameters files can be opened by means of Microsoft Excel® or any other spreadsheet tool. This is useful for debugging or cross-checking the controller settings. Nevertheless, m*odifications 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:

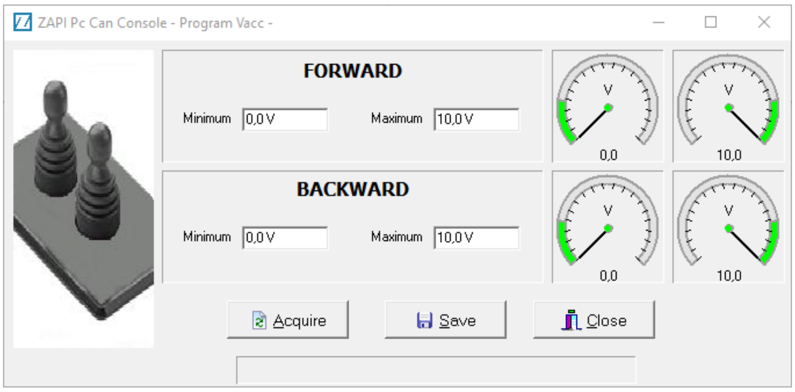
- The values as they are saved within the controller ("Value" column).
- The values as they are shown by the console or similar tools ("Scaled Value" column).
- The name of the menu containing the parameter ("Name menu" column).

All the parameters can be explored by the top tabs, each one dedicated to a specific subset. 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.

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

Click on Save button to save the values acquired.

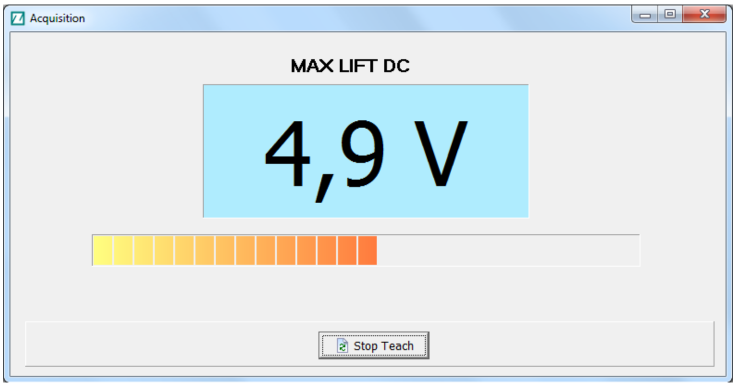
Click on Close button to close the accelerator acquisition window.

### 13.1.6 Lift & Lower acquisition

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

Choose “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.
- Press “Stop Teach” button.

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

### 13.1.7 Steering acquisition

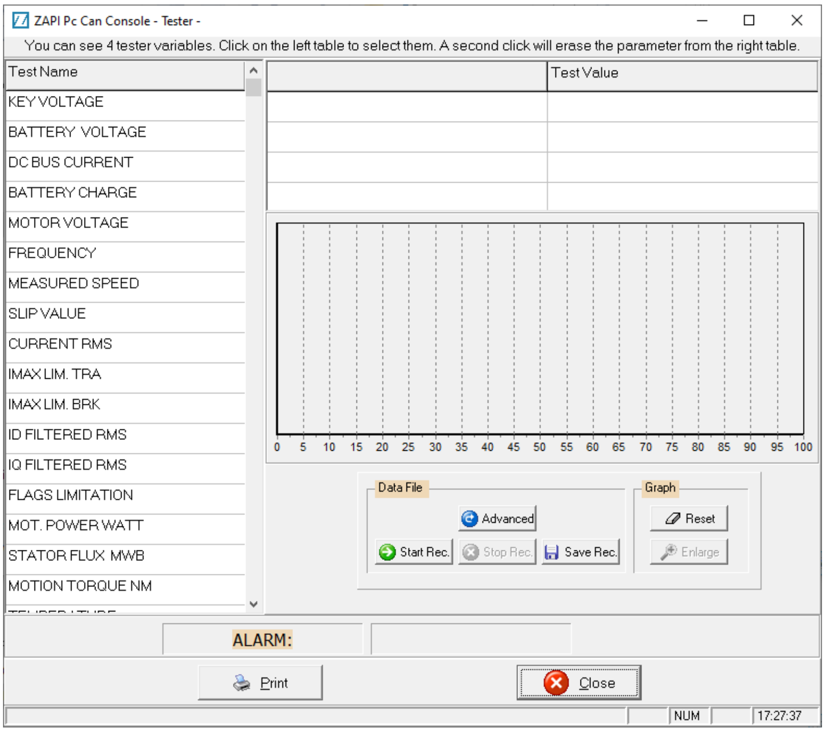
Once you have connected, you need to receive the inverter parameter; choose “Function” → “Parameter” menu (or press the “Parameter” icon).

Choose “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.

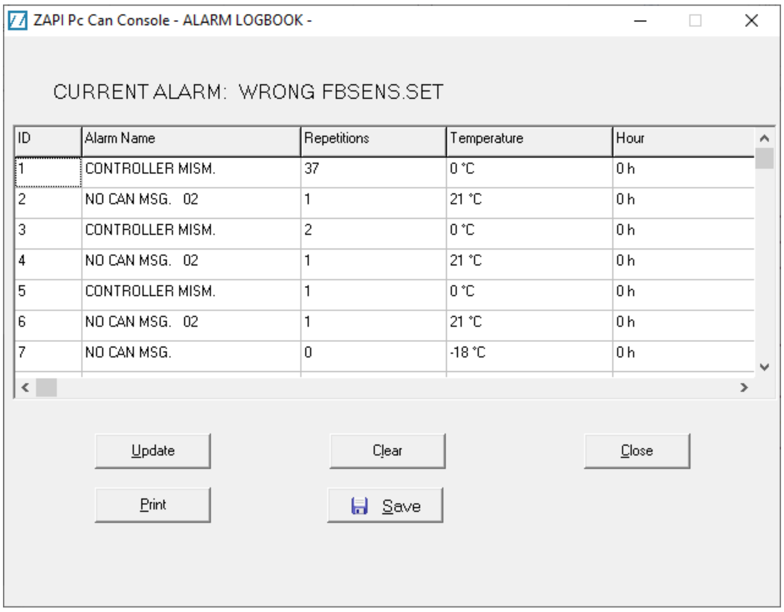



*ZAPI PC CAN Console: TESTER window.*

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. Up to four values at a time are allowed.

### 13.1.9 Alarm Logbook

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

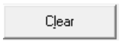



*ZAPI PC CAN Console: alarm logbook.*

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 

button to refresh the alarms list.

Click on 

button to clear the alarms list.

Click on 

or 

to print or export the alarms list in *.pdf or *.csv extension.

### 13.1.10 Monitor CAN bus

The new version of the CAN Console embeds a function of CAN bus monitor and trace recording useful for maintenance operations. Please ask Zapi technicians for instructions and usage.

## 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.

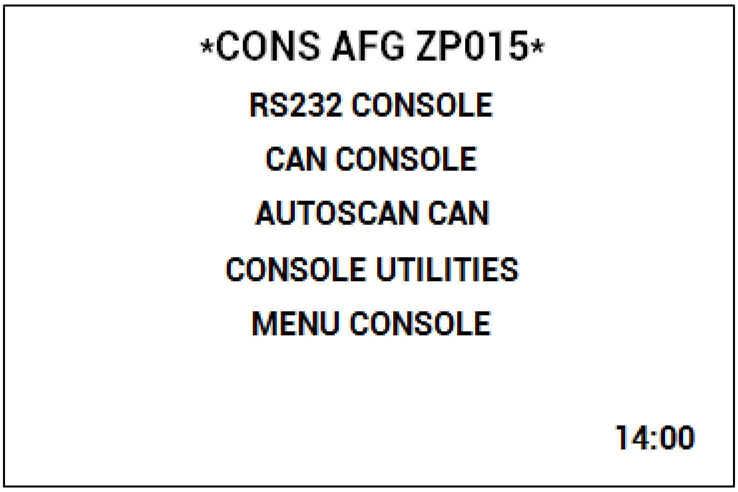
*While the Smart Console is powered from external sources on pin CNX8, the ON button is deactivated regardless of the presence of the internal batteries.*

### 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.

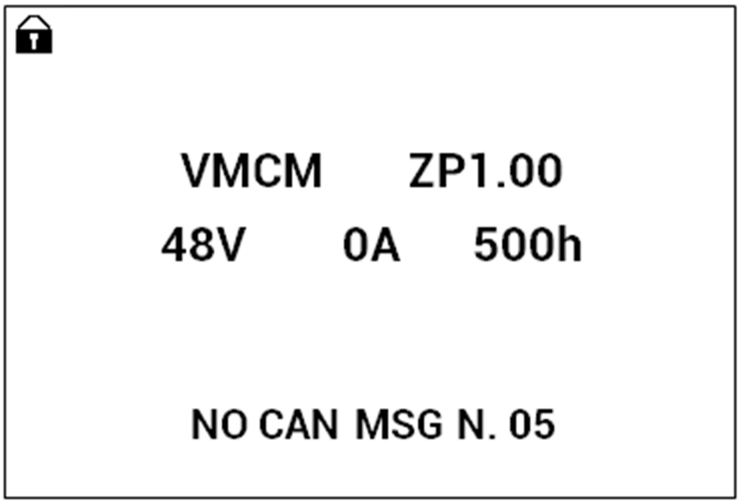
- RS232 Console: enter this menu to start a serial connection as in the Console Ultra.
- CAN Console: enter this menu to establish a CAN connection.
- AUTOSCAN CAN: another way to establish a CAN connection.
- Console Utilities and Menu Console: ignore them at the moment.
- The current time is shown at the bottom right.
- The green LED should be steady on.

The “RS232” console is already highlighted upon start-up. Press 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.

---

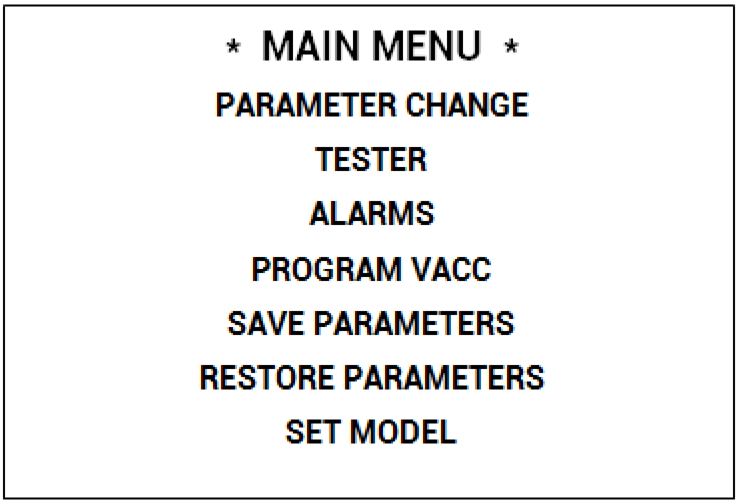
*Refer to the Smart Console manual for more details about the read-only mode.*

---

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 the controller nominal voltage and current, along with the hour meter.
- Last line shows the present alarm, if any alarm is present.

Press OK to access the MAIN MENU.

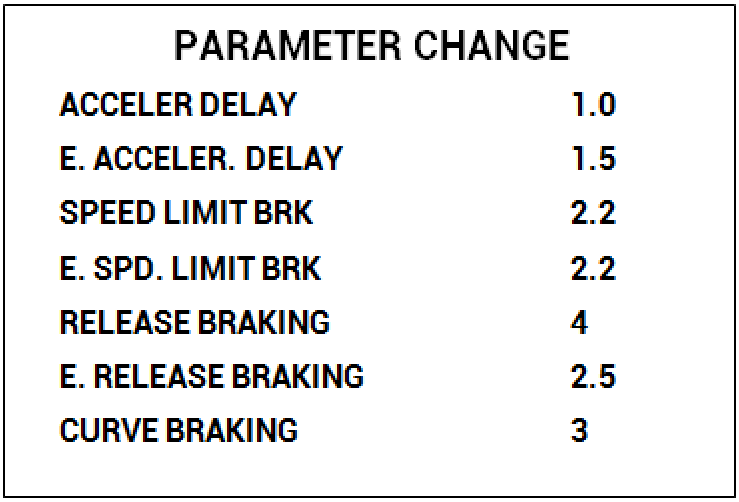



MAIN MENU contains the complete list of submenus available in the controller. Unlike the Console Ultra, here, there are no "hidden" menus which must be reached by some combinations of buttons; all menus are visible.

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

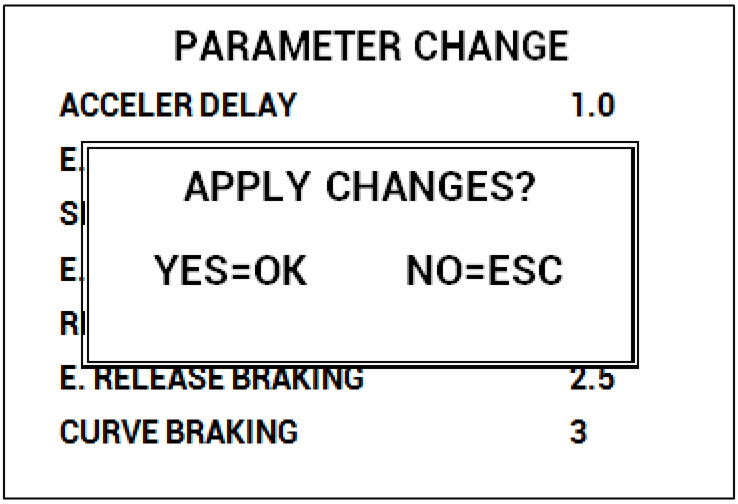
From the MAIN MENU enter the desired submenu (for example the PARAMETER CHANGE menu).




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:

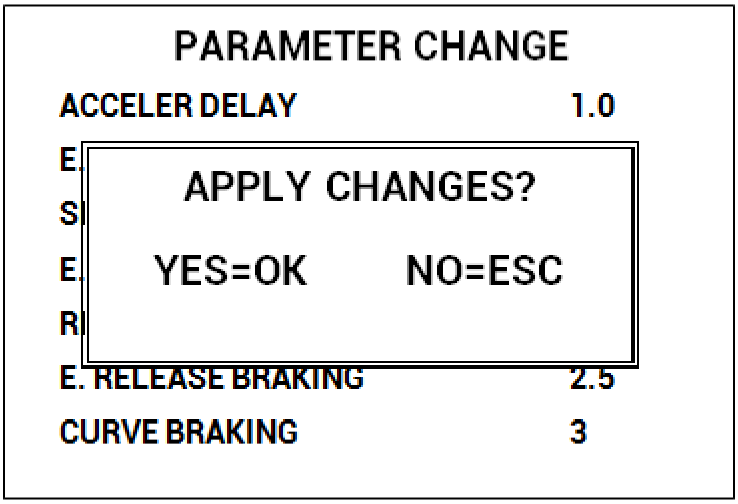
- select the enable switch, if any;
- select the control switch, if any (either lift or lower);
- slide the control sensor (lift/lower potentiometer) to the correct position in agreement with the acquisition that you are performing. The displayed values change while sliding/rotating the potentiometer.

---

*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

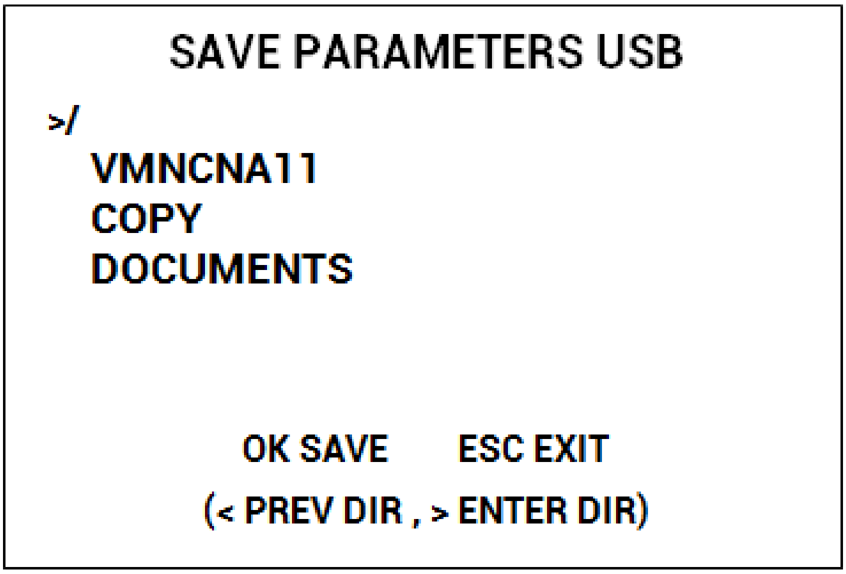
The complete list of parameters is saved as a csv file in order to be opened with Microsoft Excel® or any other spreadsheet tool.
The file is formatted in the same way as with the PC CAN Console. Thus, it contains the whole list of parameter and, for each one, various fields are available, in particular:

- 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 file system. 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:

1. Navigate the directory list and go into the directory where you want to save the parameters.
2. 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.
3. Press OK to start the parameter download. A progression bar shows the ongoing process.
4. 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.***