(EN)

*User Manual*

# ACE2 2uC

**Copyright © 1975-2017 Zapi S.p.A.**
**All rights reserved**

# Contents

**APPROVAL SIGNS**

| COMPANY FUNCTION | INITIALS | SIGN |
|---|---|---|
| PROJECT MANAGER | | |
| TECHNICAL ELECTRONIC MANAGER VISA | | |
| SALES MANAGER VISA | | |

# 1 INTRODUCTION

## 1.1 About this document

### 1.1.1 Scope of this manual

This manual provides important information about ACE2 controller: it presents instructions, guidelines and diagrams related to installation and maintenance of the controller in an electrically powered vehicle.

### 1.1.2 Manual revision

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

### 1.1.3 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 these boxes.**

## 1.2 About the Controller

### 1.2.1 Safety

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

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

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

### 1.2.2 OEM 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.

### 1.2.3 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

ACE2 inverter is a controller designed to control AC induction, BLDC and PMAC motors, in the range from 5 kW to 12 kW continuous power, used in a variety of battery-powered material-handling trucks.

Typical applications include, but are not limited to: counterbalanced trucks with load up to 2 metric tons, reach trucks, order pickers, tractors, aerial access equipment (telescopic booms and scissor lifters).

The main inverter features are:
- 16 bits microcontroller for motor control and main functions (master microcontroller), 320+ kbyte embedded flash memory
- 16 bits microcontroller for safety functions (supervisor microcontroller), 320+ kbyte embedded flash memory
- Field-oriented motor-control algorithm
- Smooth low-speed control
- Zero-speed holding control
- Zapi patented sensorless and sense-coil control
- Driver for line-contactor coil
- Driver for electromechanical brake
- Drivers for PWM-modulated voltage- controlled electrovalves or PWM-modulated current- controlled proportional valve
- Overload, short-circuit and open- load protection
- Thermal cutback, warnings, and automatic shutdown provide protection to the motor and the controller
- Optically isolated and ESD- protected CAN bus interface
- Software downloadable via serial link (external connector available) or CAN bus interface (external connector)
- Diagnostics provided via CAN bus interface using Zapi CAN Pc Tool
- Rugged sealed housing and connectors meeting IP65 environmental sealing standards for use in harsh environments

ACE2 is available in two configurations:

1) **ACE2** (24V, 36/48V, 72/80V, 96V): standard ACE2.

2) **ACE2 PW** (24V, 36/48V, 72/80V, 96V): ACE2 with enhanced power-delivery capability.

## 2.2  Technical specifications

Motor type:........................... Induction AC, BLDC and PMAC three-phase motors
Control mode: .......................... Speed or Torque control based on microcontroller
Switching frequency:................................................................................8 kHz
Ambient operating temperature range: ............................................-40 °C ÷ 40 °C
Ambient storage temperature range: ...............................................-40 °C ÷ 85 °C
Connector: ........................................................................... Ampseal 23 pins
Package Environmental Rating: .......................................................................IP65

## 2.3  Current ratings

| Model | Nominal battery voltage | Two-minute rated current [Arms] | Continuous rated current [Arms] |
|-------|-------------------------|---------------------------------|---------------------------------|
| ACE2 | 24V | 450 | 225 |
| | 24V | 400 | 200 |
| | 36/48V | 400 | 200 |
| | 36/48V | 350 | 170 |
| | 72/80V | 250 | 125 |
| | 96V | 215 | 105 |
| ACE2 PW | 24V | 550 | 270 |
| | 24V | 500 | 250 |
| | 36/48V | 500 | 250 |
| | 36/48V | 450 | 225 |
| | 72/80V | 350 | 175 |
| | 96V | 300 | 150 |

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

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

*Internal algorithms automatically reduce the maximum current when heat sink temperature exceeds 85°C. Heat sink temperature is measured internally near the power MOSFETs (see paragraph 6.6.1).*

## 2.4  DC Supply Voltage Ratings

| Nominal voltage | 24V | 36/48V | 72/80V | 96V |
|---|---|---|---|---|
| Conventional working voltage | 19,2V ÷ 57,6V | 28,8V ÷ 57,6V | 57,6V ÷ 96V | 76,8V ÷ 115,2V |
| Non-operational overvoltage limit | 35V | 65V | 115V | 130V |
| Non-operational undervoltage limit | 10V | 10V | 30V | 30V |

*Conventionally, the controller may be set to operate without alarm in the range 80% to 120% of the nominal battery voltage. With a different DC voltage supply than specified, the controller raises an alarm.*

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

*Undervoltage is measured on the KEY input (A1); overvoltage is evaluated on the positive battery terminal +B.*

# 3 DRAWINGS

## 3.1 Mechanical drawings

### 3.1.1 ACE2 – Base plate version



Available with 150X200X40 heat sink trasversal or longitudinal fins
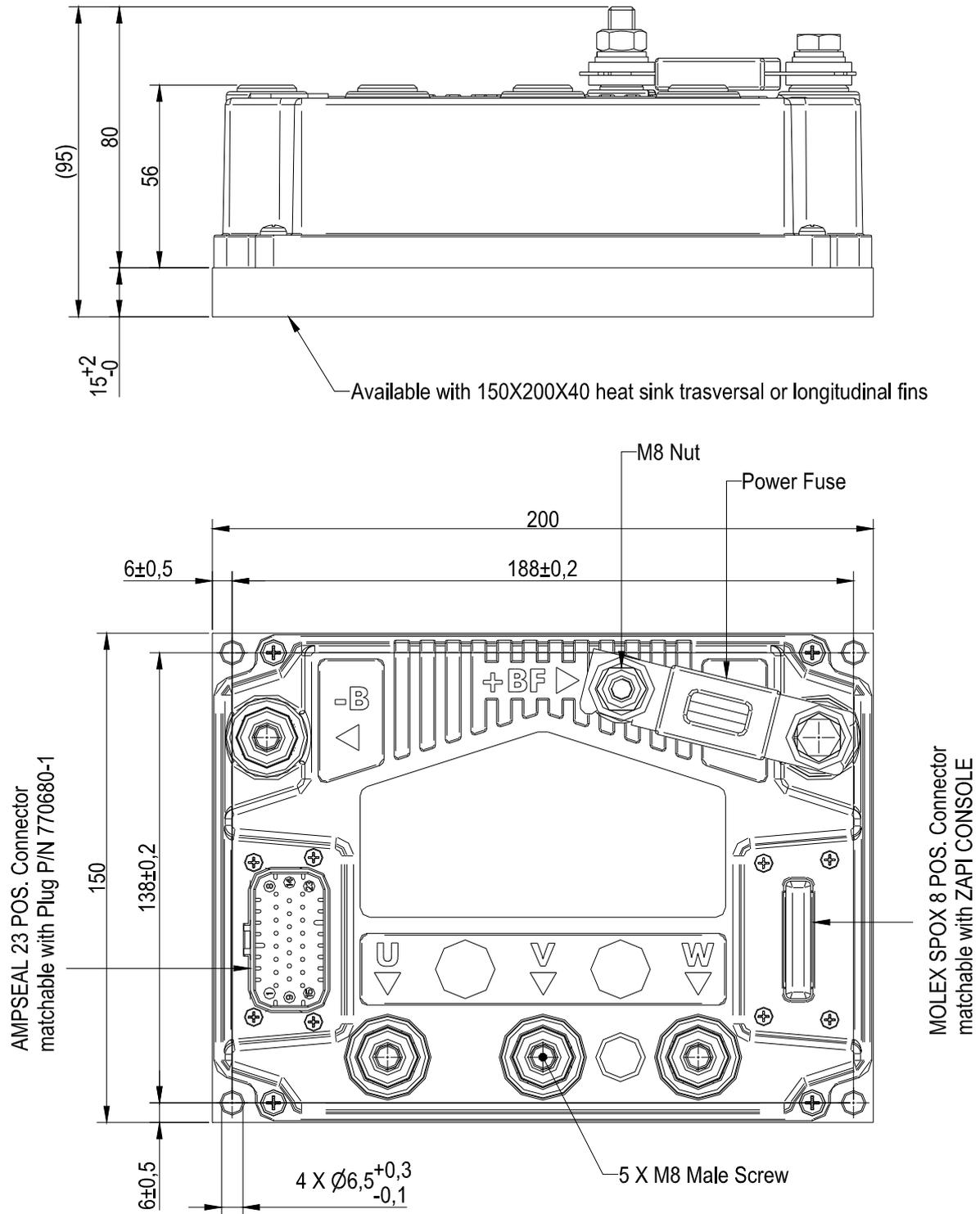
## 3.1.2  ACE2 Power – Base plate version



80

(95)

15$^{+2}_{-0}$

Available with 200X200X40 heat sink trasversal or longitudinal fins

M8 Nut

Power Fuse

200

6±0,5

188±0,2

(10,5)

(167)

−B

+BF ▷

185

173±0,2

AMPSEAL 23 POS. Connector
matchable with Plug P/N 770680-1

MOLEX SPOX 8 POS. Connector
matchable with ZAPI CONSOLE

(132,5)

U ▽    V ▽    W ▽

6±0,5

4 X Ø6,5$^{+0,3}_{-0,1}$

5 X M8 Male Screw

(14,5)

(47)    (47)    (47)
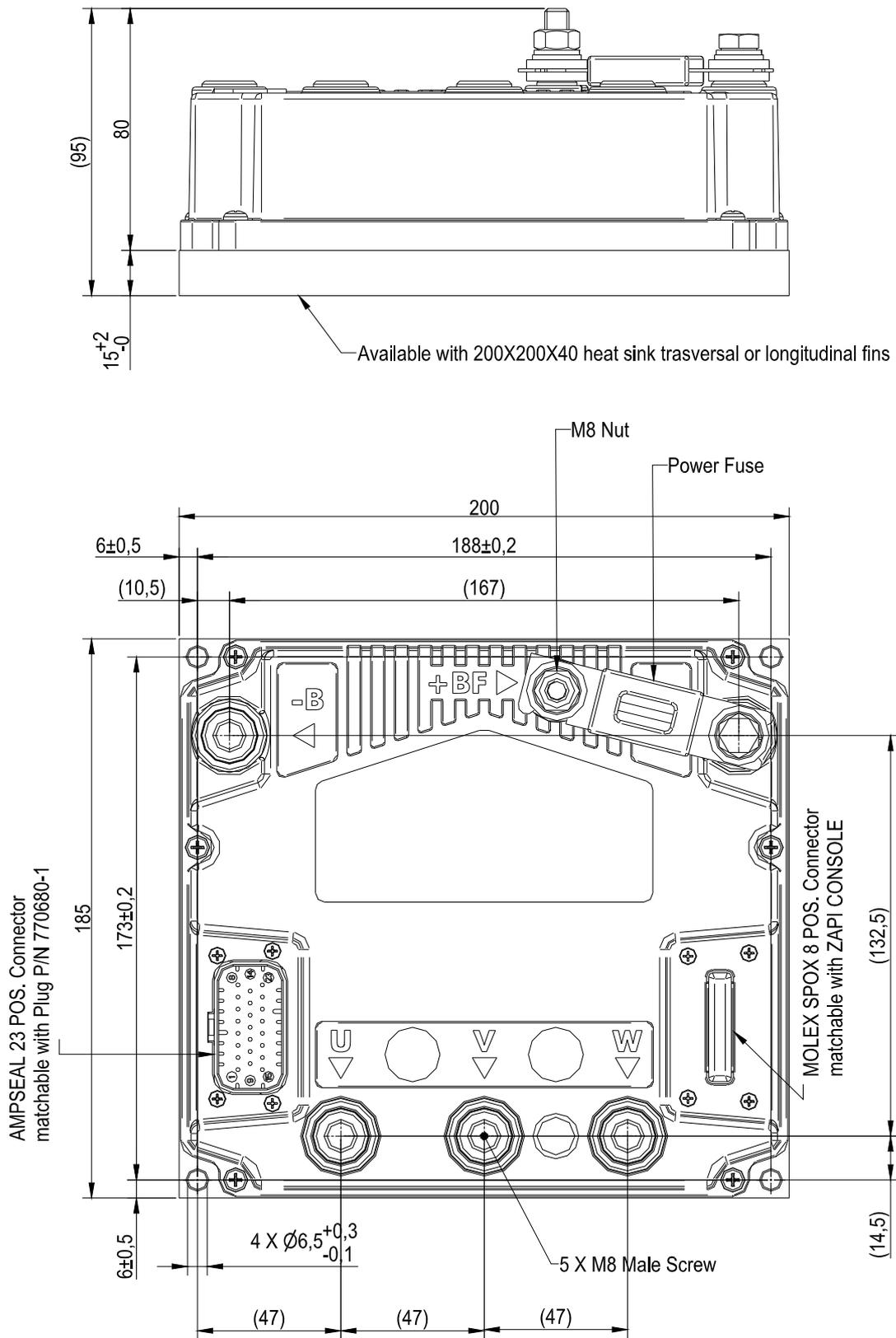
### 3.1.3  ACE2 – Longitudinal heat sink version

## 3.1.4   ACE2 Power – Longitudinal heat sink version

### 3.1.5 ACE2 – Transversal heat sink version

## 3.1.6 ACE2 Power – Transversal heat sink version

AMPSEAL Plug P/N 770680-1

80

56

40

M8 Nut

+BF

-B

ACE 2

ZAPI

ACE2 450
REGISTRATION LABEL

13.1±5
Nm

W

V

U

VOLTAGE
LABEL

5 X M8 Male Screw

200

188 +0.2 -0.2

6 +0.5 -0.5

4 X Ø6.5 +0.3 -0.1

188 +0.2 -0.2

6 +0.5 -0.5

200

### 3.1.7 ACE2 Power – High-efficiency longitudinal heat sink version

### 3.1.8 ACE2 – High-efficiency transversal heat sink version



AMPSEAL Plug P/N 770680-1

5 X M8 Male Screw

M8 Nut

ACE 2

ZAPI

ACE2 350
REGISTRATION LABEL

VOLTAGE LABEL

13.15 Nm

200
$188^{+0.2}_{-0.2}$

80

62

56

$6^{+0.5}_{-0.5}$

$138^{+0.2}_{-0.2}$

$6^{+0.5}_{-0.5}$

4 X $\phi 6.5^{+0.3}_{-0.1}$

150

## 3.1.9  ACE2 Power – High-efficiency transversal heat sink version



AMPSEAL Plug P/N 770680-1

ACE 2

ACE2 LARGE FOOTPRINT
REGISTRATION LABEL

5 X M8 Male Screw

VOLTAGE
LABEL

4 X Ø6.5 $^{+0.3}_{-0.1}$

173 $^{+0.2}_{-0.2}$

185

200

188 $^{+0.2}_{-0.2}$

6 $^{+0.5}_{-0.5}$

6 $^{+0.5}_{-0.5}$

(68)

56

62

## 3.2 Connection drawings

### 3.2.1 AC Traction configuration



NOTE1: DIFFERENT I/O CONFIGURATIONS POSSIBLE ON OEM DEMAND
NOTE2:
A16, A18, A9 = 3 INDIPENDENT, OVERCURRENT PROTECTED, VOLTAGE-CONTROLLED OUTPUTS.
OR
A16, A18 = 2 INDIPENDENT, OVERCURRENT PROTECTED, CURRENT-CONTROLLED OUTPUTS
(A9 = OPEN).

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 ACE2 2uC – TRACTION CONTROL

| | Data/Date | Tecnico/Technician FF | Serie/Series | Disegno n./Drawing n. | Pagina/Page |
|---|---|---|---|---|---|
| ZAPI s.p.a. 42028 POVIGLIO–ITALY | 03/10/17 | Visto/Visa | AS | AF2ZP43B | 1.1 |

## 3.2.2 AC Pump configuration



KEY

MC

+B

+BATT

-BATT

-B

U

AC MOTOR

V

W

THMOT    A22
         A23
PENC     A8
ENCA     A7
ENCB     A14
ENC
GND      A15

CPOT LIFT    A13

SPD2     A6
SPD3     A3
LOWER    A10
+5V      A2
LIFT     A4
SPD1     A5

A1    KEY

A17   PCOM
A19               SEAT
NMC   *   MAX 2.5A    A16
NEB   *   MAX 2.5A    A18
NAUX1 *   MAX 2A      A9

A20   CANL1
A21   CANH1
A11   CANL2
A12   CANH2

A16, A18, A9 = 3 INDIPENDENT, OVERCURRENT PROTECTED, VOLTAGE-CONTROLLED OUTPUTS.
OR
A16, A18 = 2 INDIPENDENT, OVERCURRENT PROTECTED, CURRENT-CONTROLLED OUTPUTS
(A9 = OPEN).

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 ACE2 2uC – PUMP CONTROL

| | Data/Date | Tecnico/Technician FF | Serie/Series | Disegno n./Drawing n. | Pagina/Page |
|---|---|---|---|---|---|
| ZAPI s.p.a. 42028 POVIGLIO–ITALY | 03/10/17 | Visto/Visa | AS | AF2ZP44B | 1.1 |

## 3.2.3 AC CANopen Configuration



A16, A18, A9 = 3 INDIPENDENT, OVERCURRENT PROTECTED, VOLTAGE-CONTROLLED OUTPUTS.
OR
A16, A18 = 2 INDIPENDENT, OVERCURRENT PROTECTED, CURRENT-CONTROLLED OUTPUTS
(A9 = OPEN).

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 ACE2 2uC – CANOPEN CONTROL

| | ZAPI s.p.a. 42028 POVIGLIO–ITALY | Data/Date 04/10/17 | Tecnico/Technician FF | Serie/Series AS | Disegno n./Drawing n. AF2ZP46B | Pagina/Page 1.1 |
|---|---|---|---|---|---|---|
| | | | Visto/Visa | | | |

## 3.2.4  BL Traction configuration



NOTE1: DIFFERENT I/O CONFIGURATIONS POSSIBLE ON OEM DEMAND
NOTE2:
A16, A18, A9 = 3 INDIPENDENT, OVERCURRENT PROTECTED, VOLTAGE-CONTROLLED OUTPUTS.
OR
A16, A18 = 2 INDIPENDENT, OVERCURRENT PROTECTED, CURRENT-CONTROLLED OUTPUTS
(A9 = OPEN).

ZAPI ACE2 2uC SIN/COS — TRACTION CONTROL

| ZAPI s.p.a. 42028 POVIGLIO-ITALY | Data/Date 04/10/17 | Tecnico/Technician FF | Serie/Series AS | Disegno n./Drawing n. AF2ZP47A | Pagina/Page 1.1 |
|---|---|---|---|---|---|
| | | Visto/Visa | | | |

# 4 I/O INTERFACE DESCRIPTION

## 4.1 Power connections

Power connections are on vertical posts that host power-cables lugs. On the cover of the converter they are labeled as in the following table.

| Terminal Name | Description |
| --- | --- |
| +B | Positive supply to the power stage. |
| -B | Battery negative termination. |
| U, V, W | Motor phase terminations. |

## 4.2 Ampseal connector

ACE2 is equipped with a 23-poles Ampseal connector like that of the figure. Each of the 23 pins is referred to as "A#" (always red colored for ease of spotting), where "A" denotes the connector name and "#" is the pin number, from 1 to 23.
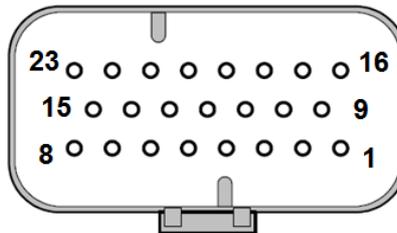


*23-poles Ampseal connector of ACE2 Standard.*

*For each I/O pin, the default Zapi function is indicated. The function of each pin can be changed in the customized software.*

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

The following table lists the functional associations for the pins of the 23-poles Ampseal connector for ACE2 in Traction and Pump configurations.

## Traction configuration

| Pin | Type | Name | Description |
|-----|------|------|-------------|
| A1 | Input | KEY | Input of the key switch signal. |
| A2 | Output | +5V | Positive supply for external potentiometers and switches (+5V 100mA maximum). |
| A3 | Input | CPOT3 | Analog input. By default it is used for the handbrake or the speed-reduction request, like a digital input (0 – 5 V). |
| A4 | Input | FWD | Digital input, active when connected to +5V.<br>The default function is as FORWARD request; closing this input the truck moves forward. |
| A5 | Input | BWD | Digital input, active when connected to +5V.<br>The default function is as BACKWARD request; closing this input the truck moves backward. |
| A6 | Input | CPOT2 | Analog input. By default it is used for the brake pedal or the quick-inversion request, like a digital input (0 – 5 V). |
| A7 | Input | ENCA | Channel A of the incremental encoder. |
| A8 | Output | PENC | Positive supply for the encoder or for another speed transducer (+12 or +5 V, 150 mA maximum). |
| A9 | Output | NAUX1 | Output of auxiliary-coil driver (driving to -B); PWM voltage controlled; 2 A maximum continuous current. |
| A10 | Input | CPOT4 | Analog input. By default it is used for the AUX1 request, like a digital input (0 – 5 V); when it is high, output NAUX1 (A9) is activated. |
| A11 | Comm. | CANL2 | Low-level signal of CAN bus interface 2. |
| A12 | Comm. | CANH2 | High-level signal of CAN bus interface 2. |
| A13 | Input | CPOT ACC | Analog input. By default it is used as accelerator reference (wiper contact of the accelerator potentiometer). |
| A14 | Input | ENCB | Channel B of the incremental encoder. |
| A15 | Output | GND | Negative supply for the encoder and for potentiometers. |

| Traction configuration | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A16 | Output | NMC | Output of the main-contactor driver (driving to -B); PWM voltage controlled; 1.5A maximum continuous current. |
| A17 | Output | PCOM | Connect the positive supply of coils (MC, EB, AUX) to this pin. |
| A18 | Output | NEB | Output of the electromechanical-brake driver (driving to -B); PWM voltage controlled; 1.5A maximum continuous current. |
| A19 | Input | SEAT | Digital input, active when connected to +B.<br>The default function is as SEAT (or TILLER) input. |
| A20 | Comm. | CANL1 | Low-level signal of CAN bus interface 1. |
| A21 | Comm. | CANH1 | High-level signal of CAN bus interface 1. |
| A22 | Sens. | THMOT | Positive terminal for the motor thermal sensor. The internal pull-up is a fixed 2 mA current source (max 5 V). |
| A23 | Sens. | | Negative terminal for the motor thermal sensor. |

### Pump configuration

| Pump configuration | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A1 | Input | KEY | Input of the key switch signal. |
| A2 | Output | +5V | Positive supply for external potentiometers and switches (+5V 100mA maximum). |
| A3 | Input | SPD3 | Digital input, active when connected to +5V.<br>By default it is used for the THIRD-SPEED request; when it is high, the pump rotates at the third speed. |
| A4 | Input | LIFT | Digital input, active when connected to +5V.<br>The default function is as LIFT request; closing this input the forks are lifted. |
| A5 | Input | SPD1 | Digital input, active when connected to +5V.<br>The default function is as FIRST-SPEED request; when it is high, the pump rotates at the first speed. |

| Pump configuration | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A6 | Input | SPD2 | Digital input, active when connected to +5V. By default it is used for the SECOND-SPEED request; when it is high, the pump rotates at the second speed. |
| A7 | Input | ENCA | Channel A of the incremental encoder. |
| A8 | Output | PENC | Positive supply for the encoder or for another speed sensor (+12 or +5 V, 150 mA maximum). |
| A9 | Output | NAUX1 | Output of auxiliary-coil driver (driving to -B); PWM voltage controlled; 2 A maximum continuous current. |
| A10 | Input | LOWER | Digital input, active when connected to +5V. By default it is used for the LOWER request; when it is high, output NAUX1 (A9) is activated. |
| A11 | Comm. | CANL2 | Low-level signal of CAN bus interface 2. |
| A12 | Comm. | CANH2 | High-level signal of CAN bus interface 2. |
| A13 | Input | CPOT LIFT | Analog input. |
| A14 | Input | ENCB | Channel B of the incremental encoder. |
| A15 | Output | GND | Negative supply for the encoder and for potentiometers. |
| A16 | Output | NMC | Output of the main-contactor driver (driving to -B); PWM voltage controlled; 1.5A maximum continuous current. |
| A17 | Output | PCOM | Connect the positive supply of coils (MC, EB, AUX) to this pin. |
| A18 | Output | NEB | Output of the electromechanical-brake driver (driving to -B); PWM voltage controlled; 1.5A maximum continuous current. |
| A19 | Input | SEAT | Digital input, active when connected to +B. The default function is as SEAT (or TILLER) input. |
| A20 | Comm. | CANL1 | Low-level signal of CAN bus interface 1. |
| A21 | Comm. | CANH1 | High-level signal of CAN bus interface 1. |

| Pump configuration | | | |
|---|---|---|---|
| **Pin** | **Type** | **Name** | **Description** |
| A22 | Sens. | THMOT | Positive terminal for the motor thermal sensor. The internal pull-up is a fixed 2 mA current source (max 5 V). |
| A23 | Sens. | | Negative terminal for the motor thermal sensor. |

## 4.3  Service connector (CNB)

| **Pin** | **Name** | **Description** |
|---|---|---|
| B1 | PCLRXD | Positive serial reception (Not used: it can be unconnected). |
| B2 | NCLRXD | Negative serial reception. |
| B3 | PCLTXD | Positive serial transmission. |
| B4 | NCLTXD | Negative serial transmission. |
| B5 | GND | Negative console power supply. |
| B6 | +12 | Positive console power supply. |
| B7 | FLASH | It must be connected to pin 8 for the Flash memory programming. |
| B8 | FLASH | It must be connected to pin 7 for the Flash memory programming. |

## 4.4  External devices

### 4.4.1  Key input

KEY input (A1) is generally connected to the vehicle start key switch. It supplies battery voltage to the logic circuitry and it also pre-charges the DC-link capacitors at key-on, before main contactor closes. The KEY voltage is monitored.

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

#### Protection

KEY input is protected against reverse polarity with a diode.
Fuse FU1 (see functional drawings, paragraph 0), should be sized according to the number of motor controllers connected to it (a 10 A fuse is recommended) and the current absorption of the KEY input (input power below 15 W).

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

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

### 4.4.2  Digital inputs

Digital command devices (microswitches) must be connected to +B (typically to the key voltage through the pin PCOM A17) or to +5V (pin A2), depending on the input configuration (refer to pin description in paragraph 4.2).
Pull-down or pull-up resistors are built-in. Functional devices (like FW and BW) must be normally open, so that each associated function becomes active when the microswitch closes.

Safety-related devices (like CUTBACK) must be normally closed, so that each associated function becomes active when the microswitch opens.

Nominal voltage figures of digital inputs for ACE2 in standard Zapi configuration are listed below. Custom hardware may feature different voltage values.

| Inverter voltage | | 24V | 36/48V | 72/80V | 96V |
|---|---|---|---|---|---|
| **Logic low threshold** | A4, A5 | 1.55 V | 1.55 V | 1.55 V | 1.55 V |
| | A19 | 5 V | 5 V | 30 V | 35 V |
| **Logic high threshold** | A4, A5 | 2.65 V | 2.65 V | 2.65 V | 2.65 V |
| | A19 | 8.5 V | 8.5 V | 50 V | 60 V |

| Inverter voltage | | 24V | 36/48V | 72/80V | 96V |
|---|---|---|---|---|---|
| **Maximum input voltage** | **A4, A5** | 10V | 10V | 10V | 10V |
| | **A19** | 75V | 75V | 115V | 115V |

> ⚠️ *For critical functions, when good diagnostic 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
Digital inputs have 3.3 nF capacitors to -B for ESD protection.

### Circuit
Input impedance of digital inputs for ACE2 in standard Zapi configuration are listed below. Custom hardware may feature different impedance values.

| Inverter voltage | | 24V | 36/48V | 72/80V | 96V |
|---|---|---|---|---|---|
| **Impedance** | **A4, A5** | 1 kΩ | 1 kΩ | 1 kΩ | 1 kΩ |
| | **A19** | 20 kΩ | 20 kΩ | 52 kΩ | 52 kΩ |

### Connector position
FWD A4, BWD A5, TILLER/SEAT A19
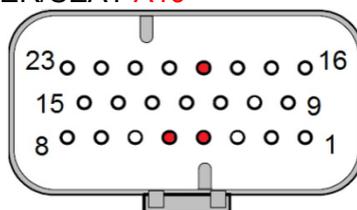


### Microswitches
- It is suggested to adopt microswitches with a contact resistance lower than 0.1 Ohm and a leakage current lower than 100 µA.
- In full-load condition, the voltage between the key-switch contacts must be lower than 0.1 V.
- If the microswitches to be adopted have different specification, it is suggested to discuss them with Zapi technicians prior to employ them.

## 4.4.3 Analog inputs

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

Analog inputs impedance = 150 kΩ.

Analog inputs are generally connected to potentiometers. The standard connection is that on the left side of the next figure: potentiometer at rest on one end in combination with a couple of travel-demand switches. On request, it is also possible to have the configuration on the right side of the figure: potentiometer at rest in the middle, still in combination with a couple of travel-demand switches.

## 3 PEDAL WIRE

## 3 HANDLE WIRE
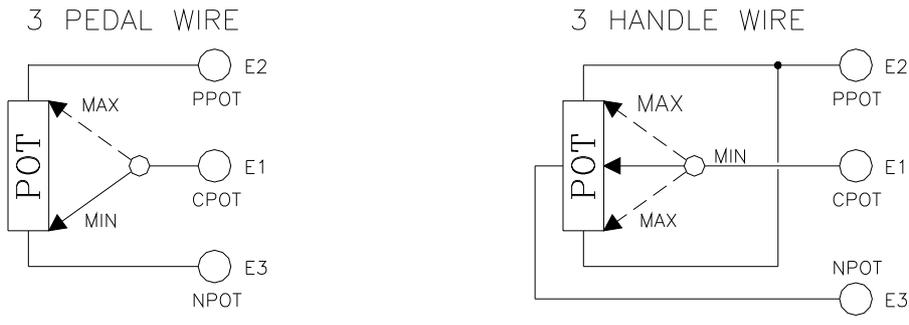
*Potentiometer configuration*

Negative terminal of the potentiometer has to be connected to pin GND A15.
Potentiometer resistance should be in the 500 Ω – 10 kΩ range; generally the load
should be in the 1.5 mA to 30 mA range.
A procedure for automatic acquisition of potentiometers signals can be carried out
using PROGRAM VACC, PROGRAM LIFT/LOWER and PROGRAM STEER
functions (see paragraphs 9.1, 9.2 and 9.3).

### General features:
- Input impedance: 150 kΩ
- Input voltage range: 0 V ÷ 10 V
- Cut-off (-3 dB) frequency: 34 Hz

### Protection
Analog inputs are protected against short circuits to +B and -B and they have 10 nF
filtering capacitors to -B for ESD protection.

### Connector position
A3, A6, A10, A13
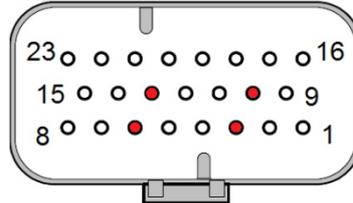


⚠️ *If an analog input is used as speed reference, a system safety strategy must
be defined. The application software must consider errors related to analog
input such as VACC OUT OF RANGE and VACC NOT OK.*

## 4.4.4 Encoder input

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

Threshold levels are:

| Encoder voltage | 5V | 12V |
|---|---|---|
| Logic low threshold | 0.9 V | 3 V |
| Logic high threshold | 2.8 V | 5 V |

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

**Protection**

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

**Connector position**

ENCA A7, ENCB A14
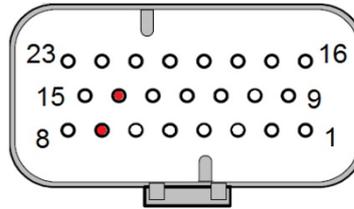


⚠️ ***It is important to verify the wiring by ensuring that encoder signals are not disturbed by motor currents or by electric motor brake.***

For more details about encoder installation also refer to paragraph 5.2.5

📝 *Note: encoder resolution and motor pole pairs are specified in the home page, which shows a headline like the following.*
*A2MT2B      ZP1.13*

*Where:*
*A2MT:   ACE2 traction controller (M stands for "Master µC", S for "Supervisor µC")*
*(A2MP:  ACE2 pump controller)*
*2: motor pole pairs number*
*B: 64 pulses/rev encoder*

*Encoder resolution is given by the last letter as:*
*A = 32 pulses/rev*
*B = 64 pulses/rev*
*C = 80 pulses/rev*
*D = 128 pulses/rev*

## 4.4.5  MC Output

Main (or line) contactor is operated through an open-drain PWM-voltage-controlled output on NMC pin A16.
In order to utilize the built-in freewheeling diode, the coil must be supplied through pin PCOM A17 (see chapter 0).
In case the vehicle design does not allow the usage of the built-in freewheeling diode, i.e. if the integrity of return path cannot be guaranteed in all situations, an external one must be applied between the coil terminals.

**Output features**

 – 1.5 A continuous current (holding current).
 – 2 A peak current (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 by software. If a different PWM frequency has to be used, it is suggested to discuss it with Zapi technicians.*

### Protection

MC output is protected against inductive discharge with internal freewheeling diode towards pin PCOM A17; ESD-protected by means of ESD-suppressing device and protected against reverse polarity of the battery.

Built-in diagnoses:
- Overcurrent
- Shorted driver
- Open Driver
- Open coil

*Overcurrent protection is applied by hardware.*

*As standard, MC output is a PWM voltage-controlled output. It can also be used as a current-controlled output.*

**To protect the controller from overvoltage caused by the inductive load, a free-wheeling diode is built-in towards pin PCOM A17.**

**Driving an inductive load on a PWM-modulated 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
NMC A16
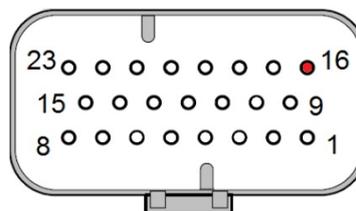


**Please ensure that the inductive load is connected such that the path for the free-wheeling diode is always intact, or use an external free-wheeling diode if this is not possible.**

⚠️ *Use of brushless fans or other loads with built-in capacitor can give high inrush current at turn on, which can give an open-drain over-current trip. The inrush current must be below the open-drain peak current.*

### 4.4.6  EB Output

Electromechanical brake is operated through an open-drain PWM-voltage-controlled output on pin NEB A18.
In order to utilize the built-in freewheeling diode, the coil must be supplied through pin PCOM A17 (see paragraph 0).
In case the vehicle design does not allow the usage of the built-in freewheeling diode, i.e. if the integrity of return path cannot be guaranteed in all situations, an external freewheeling diode must be applied between the coil terminals.

#### Output features
– 2 A continuous current (holding current)
– 2.5 A peak (pulling current) for a maximum of 200 ms.
– Individual hardware for detection of: shorted driver, open driver, open coil.
– 1 kHz 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.*

#### Protection
EB output is protected against inductive discharge with internal freewheeling diode towards pin PCOM A17; ESD-protected by means of ESD-suppressing device and protected against reverse polarity of the battery.

Built-in diagnoses:
- Overcurrent
- Shorted driver
- Open driver
- Open coil

📝 *Overcurrent protection is featured by hardware, shared with  AUX output*

📝 *As standard, EB output is a PWM voltage-controlled output. It can also be used as current-controlled output, but only if AUX output is not used.*

⚠️ *Driving an inductive load on a PWM-modulated 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**
NEB A18
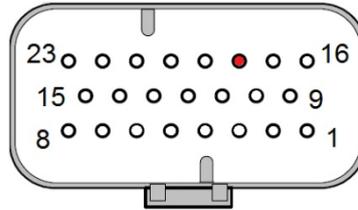


⚠️ *To protect the controller from overvoltage caused by the inductive load, a free-wheeling diode is built-in towards pin PCOM A17.*

⚠️ *Please ensure that the inductive load is connected such that the path for the free-wheeling diode is always intact, or use an external free-wheeling diode if this is not possible.*

⚠️ *Use of brushless fans or other loads with built-in capacitor can give high inrush current at turn on, which can give an open-drain over-current trip. The inrush current must be below the open-drain peak current.*

## 4.4.7 Auxiliary output

One open-drain PWM-modulated voltage-controlled output is available for operating an auxiliary service. In order to utilize the built-in free-wheeling diodes, the load must be supplied from pin PCOM A17 (see chapter 0).
In case the vehicle design does not allow the usage of the built-in freewheeling diodes, i.e. if the integrity of return paths cannot be guaranteed in all situations, an external freewheeling diode must be applied between the coil terminals of the inductive load.

### Output features
− 1.5 A continuous current (holding current).
− 2 A peak current (pulling current) for a maximum of 200 ms.
− Individual hardware for detection of shorted and open driver and open coil.
− 1 kHz PWM frequency.
− Configurable output voltage, by means of separate parameters for pulling and holding stages.

### Protection
Auxiliary outputs is protected against inductive discharge with an internal freewheeling diodes towards pin PCOM A17; ESD protected by suppressor device and protected against reverse polarity of the battery.
Built-in diagnoses:
- Overcurrent
- Shorted driver
- Open driver
- Open coil

📝 *Overcurrent protection is featured by hardware and it is shared with EB output.*

📝 *AUX output cannot be used in case EB output is used as a PWM current-controlled*

*output.*

---

⚠️ *Driving an inductive load on a PWM-modulated 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**
NAUX1 A9
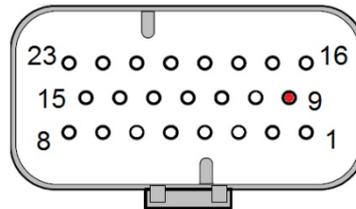


---

⚠️ *To protect the controller from overvoltage caused by the inductive load, a free-wheeling diode is built-in towards pin PCOM A17.*

⚠️ *Please ensure that the inductive load is connected such that the path for the free-wheeling diode is always intact, or use an external free-wheeling diode if this is not possible.*

⚠️ *Use of brushless fans or other loads with built-in capacitor can give high inrush current at turn on, which can give an open-drain over-current trip. The inrush current must be below the open-drain peak current.*

---

### 4.4.8 Motor-temperature measurement

Input for motor-temperature sensor, for measuring the temperature of motor windings, is available on pin THMOT A22.
Compatible temperature sensors are like:
- KTY84 with 1000Ω @ 100°C
- KTY83 with 1670Ω @ 100°C
- PT1000 with 1385Ω @ 100°C
- on/off

**Protection**
THMOT input is protected against short circuits to +B and ESD protected by suppressor device. A low-pass filter attenuates the noise from the motor.

**Connector position**
THMOT A22



---
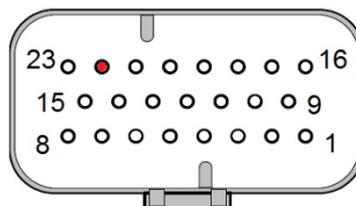
### 4.4.9 Sensor supply

Supply for external motor-speed transducer is available on pin PENC A8. Output voltage is customizable through an internal jumper to 12 V or 5 V. Maximum output current is 100 mA.

*Actual values for 12 V and 5 V are respectively 11 ± 0.5 V and 5 ± 0.2 V.*

**Protection**

Sensor-supply output is protected against overcurrent and accidental connection to +B by means of a diode.

**Connector position**

PENC A8
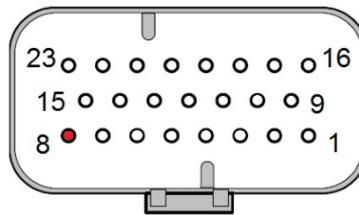


### 4.4.10 Analog supply

Supply for external analog sensors and analog speed or brake potentiometers is available on pin A2.
Output voltage is +5 V and maximum output current is 100 mA.

*Actual voltage can be 5 ± 0.3 V.*

**Protection**

Analog supply output is protected against over current with a thermal shut down and protected against accidental connection to B+ with a diode.

**Connector position**

+5V A2
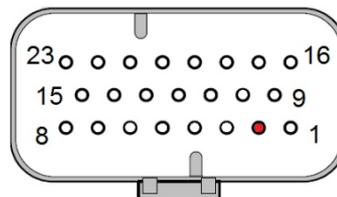


### 4.4.11 CAN bus

CAN bus interface is available for communication with the controller, featuring:
– Physical Interface according to ISO 11898-2.
– Data rate can be 125, 250 or 500 kbit/s.
– CAN driver is +5 V supplied and provides a rail to rail signal on the differential output (CANH - CANL).
– An internal 120 Ω termination resistor can be built-in.
– Common-mode filter (resistors and capacitor) is present.

### Protection

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

### Connector position

CANL1 A20,   CANH1 A21,
CANL2 A11,   CANH2 A12



---
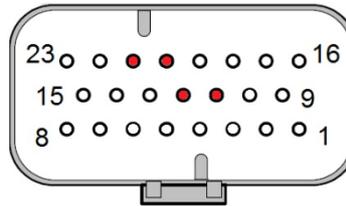
*CAN-cabling shall use a pair of twisted wires for CAN_H and CAN_L wires.*

*The CAN-cabling shall have a characteristic impedance of 120 Ω and both physical ends of the CAN Bus shall be terminated with 120 Ω between CAN_H and CAN_L for best possible noise immunity.*

*In case of isolated CAN Bus line contact Zapi technicians for the proper HW configuration of CAN Bus interface.*

---

# 5 INSTALLATION HINTS

This section presents a general procedure for startup and verification of ACE2 controller after installation on a vehicle.

The motor controller is a software configurable device. In a CAN supervisor system, some or all aspects of setup and operations may be managed by a vehicle master controller communicating over the CAN bus. For standalone operation (primarily the I/O version), customized software must be installed in the motor controller.

Built-in diagnostics functions monitor battery voltage, heat-sink temperature, motor temperature and other conditions. Error and warning events are available to the master controller, stored in a log for service access (see chapter 10)

Events log provides additional information as well as procedures for pinpointing and eliminating causes for warnings and errors.

⚠️ *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 before applying power for the first time.*

## 5.1 Material overview

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

### 5.1.1 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 with section of 50 mm² or more. For optimum inverter performance, cables from the battery should run side by side and be as short as possible.

Screwing torque for the power connections must be in the 13 ÷ 15 Nm range.

### 5.1.2 Contactor

Main contactor has 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 down to the percentage set in MC VOLTAGE RED. . This feature is useful to decrease the power dissipation of the coil and its heating.

### 5.1.3 Fuses

- Use a 10 A fuse for protection of the auxiliary circuits.
- For the protection of the power unit, refer to chapter 11. The fuse value shown is the maximum allowable. For special applications or requirements these values can be reduced.
- For safety reasons, we recommend the use of protected fuses in order to prevent the spreading of particles in case a fuse blows.

- Selection of appropriate fuse ratings is a system design issue and falls under the OEMs responsibility.

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

## 5.2  Installation of the hardware

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

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

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

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

### 5.2.1  Positioning and cooling of the controller

Install the inverter with the base-plate on a flat metallic surface.
- Ensure that the installation surface is clean and unpainted.
- Apply a light layer of thermo-conductive grease between the two surfaces to permit good heat dissipation.
- Ensure that cable terminals and connectors are correctly connected.
- Fit transient suppression devices to the horn, solenoids and contactors not connected to the controller.
- Ensure the compartment to be ventilated and the heat-sinking materials ample.
- Heat-sinking material and should be sized on the performance requirement of the machine. Abnormal ambient temperatures should be considered. In situations where either external ventilation is poor or heat exchange is difficult, forced ventilation should be used
- Thermal energy dissipated by the power module varies with the current drawn and with the duty cycle.

### 5.2.2  Wirings: power cables

- Power cables must be as short as possible to minimize power losses.
- They must be tightened onto the controller power posts with a torque in the 13 Nm – 17 Nm range.

- ACE2 should only be connected to a traction battery. Do not use converters outputs or power supplies. For special applications please contact the nearest Zapi Service Centre.

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

## 5.2.3 Wirings: CAN bus connections and possible interferences

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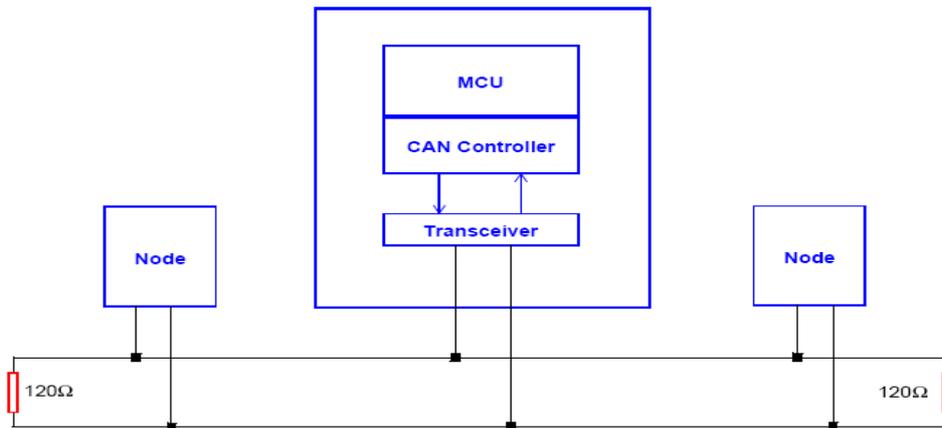


- The best type of cables for CAN bus connections is the twisted pair; if it is necessary to increase the immunity of the system to disturbances, a good choice would be to use shielded cables, where the shield is connected to the frame of the truck. Sometimes it is sufficient a not shielded two-wire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

- In a system like an industrial truck, where power cables carry currents of hundreds of Ampere, voltage drops due to the impedance of the cables may be considerable, and that could cause errors on the data transmitted through the CAN wires. The following figures show an overview of wrong and right layouts for the routing of CAN connected systems.

⚠ *Wrong Layout:*
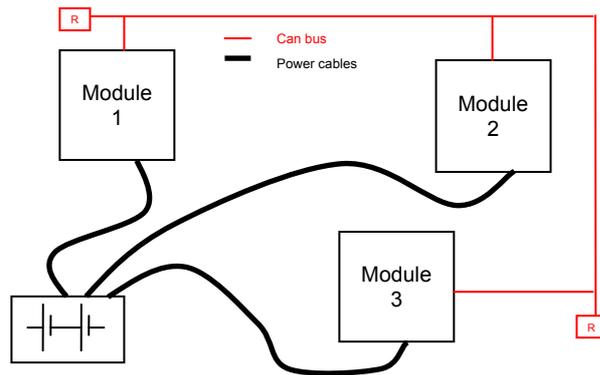


Red lines are CAN bus wires.
Black boxes are different modules, for example a traction controller, a pump controller and a display connected via CAN bus.
Black lines are the power cables.
This is apparently a good layout, but actually it can bring to errors onto the CAN line.
The best solution depends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

⚠ *Correct Layout:*
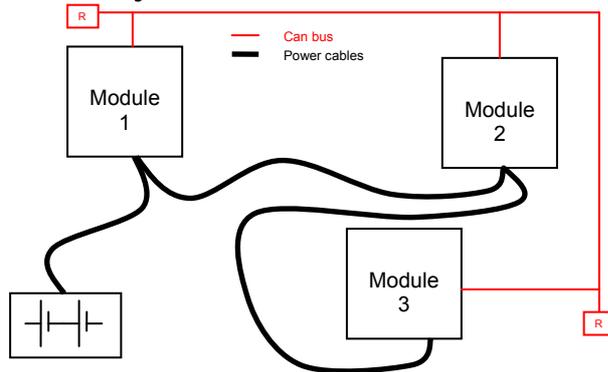


*Note: Module 1 power > Module 2 power > Module 3 power*

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

⚠️ *Correct Layout:*
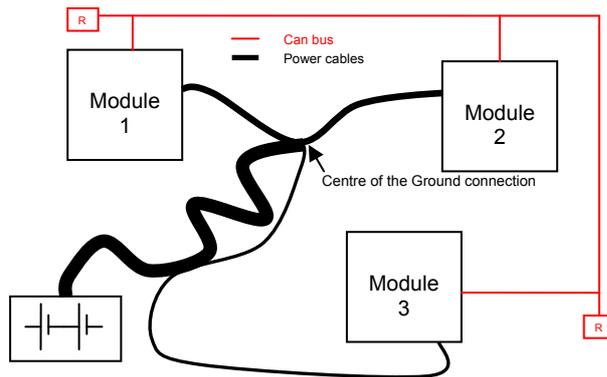


*Note: Module 1 power ≈ Module 2 power > Module 3 power*

In this case, the power cables of the two similar controllers must be as short as possible. Of course also the diameter of the cables concurs in the voltage drops described before (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 voltage drop problems and considering the current drawn from the battery by the overall system.

📝 *The complexity of modern systems needs more and more data, signal and information must flow from a node to another. CAN bus is the solution to different problems that arise from this complexity.*
*- simple design (readily available, multi sourced components and tools)*
*- low costs (less and smaller cables)*
*- high reliability (fewer connections)*
*- ease of analysis (easy connection with a pc for sniffing the data being transferred onto the bus).*

### 5.2.4  Wirings: I/O connections

- After crimping cables, verify that all strands are entrapped in the wire barrel.
- Verify that all crimped contacts are completely inserted in the connector cavities.
- For information about pin assignment, see chapter 4.

⚠️ ***A cable connected to the wrong pin can lead to short circuits and failures; so, before turning on the truck for the first time, verify with an ohmmeter the continuity between the starting point and the end of signal wires.***

### 5.2.5 Connection of encoder

ACE2 can handle different types of encoder. To control AC motor, it is necessary to install an incremental encoder with 2 phases shifted by 90°. The encoder supply can be 5 V or 12 V. For special applications it is possible to install incremental encoder with zero-position signal.

A8      +5V/+12V    encoder positive power supply.
A15     GND          encoder negative supply.
A7      ENC A       encoder phase A.
A14     ENC B       encoder phase B.
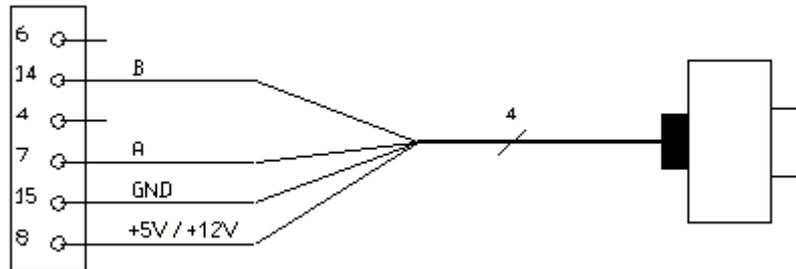


*Connection of a standard encoder.*

⚠️    *VERY IMPORTANT*
*It is necessary to specify in the commercial order the type of encoder used, in terms of power supply and electronic output, so that the logic can be properly set by Zapi lines.*

⚠️    *VERY IMPORTANT*
*The number of pulse/rev can be properly set using the dedicated parameters (see paragraph 8.2.5).*

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

⚠️    *VERY IMPORTANT*
*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.*

### 5.2.6 Connection of a sin/cos 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. At the first key-on, an auto-teaching procedure has to be performed so to acquire the sensor signals.

A2           +5V          sensor positive supply.
A15         GND         sensor negative power supply.
A3 + A13    SIN          sine signal.
A10 + A6    COS         cosine signal.
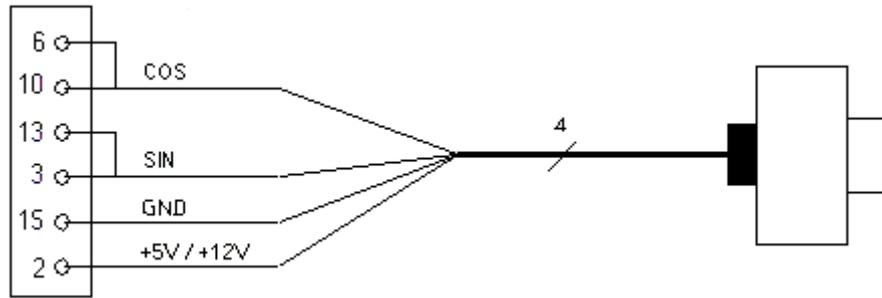
*Connections of a sin/cos sensor.*

⚠ **VERY IMPORTANT**
***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.***

### 5.2.7  Connection of Hall sensors

When the PMSM is of the BLDC type, it must be controlled with a six steps inverter (trapezoidal waves). A PMSM is a BLDC when, by turning its shaft lightened, the electromotive force between two motor terminals is of trapezoidal shape.
To control BLDC motor with Zapi inverter, it is necessary to three Hall sensors. Hall sensors power supply can be +5 or +12 V.

A8       +5V/+12V   Hall sensor positive supply.
A15      GND        Hall sensor negative supply.
A7       HS1        Hall sensor 1 signal.
A14      HS2        Hall sensor 2 signal.
A5       HS3        Hall sensor 3 signal.
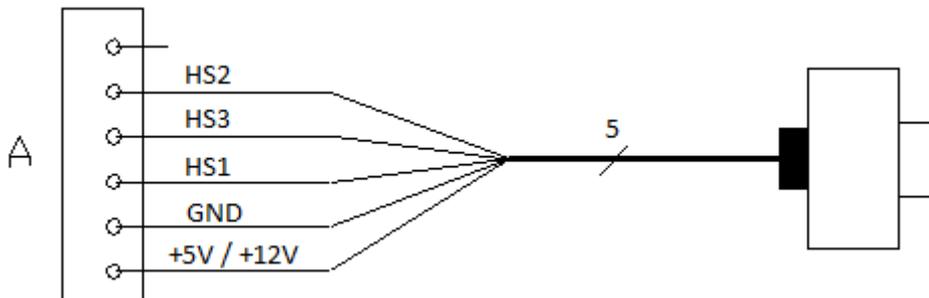


*Connection of Hall sensors.*

⚠ **VERY IMPORTANT**
***Since the logic unit and the software must be set in the correct way by Zapi lines, 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.***

### 5.2.8  Connection of main contactor and key switch

-    The connection of the main contactor can be carried out as the following figure.
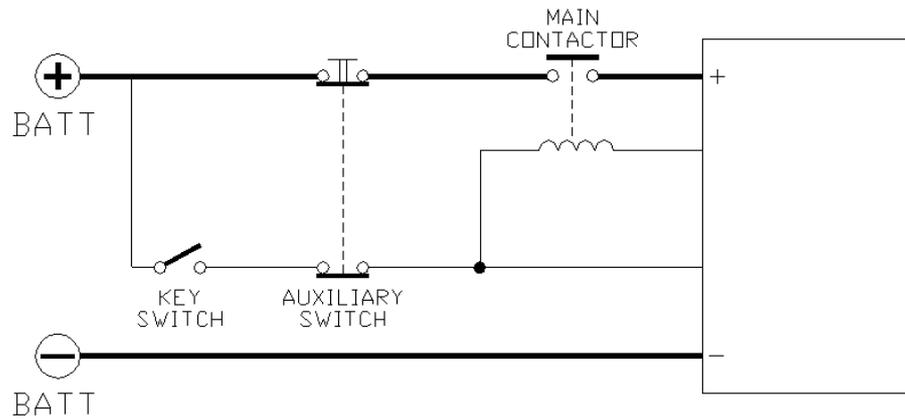
*Connection of main contactor and key switch.*

- The connection of the battery line switches must be carried out following instructions from Zapi.
- If a mechanical battery line switch is installed, it is necessary that the key supply to the inverter is open together with power battery line; if not, the inverter may be damaged if the switch is opened during a regenerative braking.
- An intrinsic protection is present against battery voltages above 140% of the nominal one and against the key switching off before disconnecting the battery power line.

### 5.2.9 Insulation of truck frame

⚠️ *As stated by EN-1175 "Safety of machinery – Industrial truck", chapter 5.7, "there shall be no electrical connection to the truck frame". So the truck frame has to be isolated from any electrical potential of the truck power line.*

## 5.3 EMC

⚠️ *EMC and ESD performances of an electronic system are strongly influenced by the installation. Special attention must be given to lengths, paths and shielding of the electric connections. These aspects are beyond of Zapi control. Zapi can offer assistance and suggestions on EMC related problems, basing on its long experience. However, <u>ZAPI declines any responsibility for non-compliance, malfunctions and failures, if correct testing is not made. The machine manufacturer holds the responsibility to carry out machine validation, based on existing norms (EN12895 for industrial truck; EN50081-2 for other applications).</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.
So the analysis works in two directions:

1) The study of the emission problems, the disturbances generated by the device and the possible countermeasures to prevent the propagation of that energy; we talk about "conduction" issues when guiding structures such as wires and cables are involved, "radiated emissions" issues when it is studied the propagation of electromagnetic energy through the open space. In our case the origin of the disturbances can be found inside the controller with the switching of the MOSFETs at high frequency which can generate RF energy. However wires have the key role to propagate disturbs because they work as antennas, so a good layout of the cables and their shielding can solve the majority of the emission problems.

2) The study of the immunity can be divided in two main branches: protection from electromagnetic fields and from electrostatic discharge. The electromagnetic immunity concerns the susceptibility of the controller with regard to electromagnetic fields and their influence on the correct work made by 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 created on a material and it remains there, 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 serial communications (CAN bus) which are spread everywhere on the truck and which may carry critical information.
   - In the worst case and 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 definitive failure of the electronic device.

---

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

---

There are different solutions for EMC issues, depending on the required level of emissions/ immunity, the type of controller, materials and position of the wires and electronic components.

1) EMISSIONS. Three ways can be followed to reduce the emissions:
   - SOURCE OF EMISSIONS: finding the main source of disturb and work on it.
   - SHIELDING: enclosing contactor and controller in a shielded box; using shielded cables;
   - LAYOUT: a good layout of the cables can minimize the antenna effect; cables running nearby the truck frame or in iron channels connected to truck frames are generally a suggested not expensive solution to reduce the emission level.

2) ELECTROMAGNETIC IMMUNITY. The considerations made for emissions are valid also for immunity. Additionally, further protection can be achieved with ferrite beads and bypass capacitors.

3) ELECTROSTATIC IMMUNITY. Three ways can be followed to prevent damages from ESD:

- PREVENTION: when handling ESD-sensitive electronic parts, ensure the operator is grounded; test grounding devices on a daily basis for correct functioning; this precaution is particularly important during controller handling in the storing and installation phase.
- ISOLATION: use anti-static containers when transferring ESD-sensitive material.
- GROUNDING: when a complete isolation cannot be achieved, a good grounding can divert the discharge current trough a "safe" path; the frame of a truck can works like a "local earth ground", absorbing excess charge. So it is strongly suggested to connect to truck frame all the parts of the truck which can be touched by the operator, who is most of the time the source of ESD.

## 5.4  Various suggestions

- Never connect SCR low frequency chopper with asynchronous inverter because the asynchronous filter capacitors alter the functioning of the SCR choppers. If it is necessary to use two or more control units (for example  traction and lift), they must belong to the ZAPIMOS family.
- During battery charge, disconnect asynchronous from the battery.

# 6 FEATURES

## 6.1 Operational features

- Speed control (three versions available: sensored, sense coil and sensorless, as explained in the introduction section).
- Optimum behavior on a slope due to the speed feedback: the motor speed follows the accelerator, starting a regenerative braking if the speed exceeds the setpoint.
- Electrical stop on a ramp: the machine is electrically held on a slope for a programmable time (see also paragraph 8.2.2).
- Stable speed in every position of the accelerator.
- Regenerative release braking based upon deceleration ramps.
- Regenerative braking when the accelerator pedal is partially released (deceleration).
- Direction inversion with regenerative braking based upon deceleration ramp.
- Regenerative braking and direction inversion without contactors: only the main contactor is present.
- 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).
- The inverter settings can drive an electromechanical brake.
- Hydraulic steering function:
  - When ACE2 works as traction inverter:
    - The traction inverter sends a "hydraulic steering function" request to the pump inverter on the can-bus line.
      Moreover, if the pump inverter is not present (for ex: tractor application), the traction inverter can manage a "hydraulic steering function" by driving a hydro contactor which drive a hydraulic steering motor (output A18), see also OPTIONS chapter.
  - When ACE2 works as pump inverter:
    - The pump inverter manages a "hydraulic steering function". That is, it drives the pump motor at the programmed speed for the programmed time.
- High efficiency of motor and battery due to high frequency commutations.
- Double microcontroller for safety functions

## 6.2 Dual traction motor

In the case of dual traction motors, there is additional processing of the associated steering signal (from a potentiometer or switches) in order to generate separate torque demands for the left and right motors of the vehicle. This allows the two motors to be operated at different speeds, which greatly assists in turning the vehicle and prevents wheel scrub. After the torque demands have been generated, the operation of each motor control system is as described in the case of a single traction motor.

## 6.3  Pump motor

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

## 6.4  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 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 down hill, a maximum vehicle speed can be set.

## 6.5  Speed mode

In this mode the controller maintains the motor at a constant speed for a given throttle position as long as sufficient torque is available. Speed mode differs from torque mode in that the torque value applied to the motor is calculated by the controller based on the operator's requested speed (determined by throttle position) and the vehicle's actual speed.

## 6.6  Protection and safety features

### 6.6.1  Protection features

The ACE2 is protected against some controller injuries and malfunctions:
- **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.
- **Voltage monitoring**
  Protected against battery undervoltage and overvoltage.
- **Thermal protection**
  If the controller temperature exceeds 85 °C, the maximum current is reduced in proportion to the thermal increase. The temperature can never exceed 105 °C.

Imax

MAXIMUM CURRENT = 100%

MAXIMUM CURRENT = 75%

MAXIMUM CURRENT = 50%

85°C  90°C  95°C  105°C  T(°C)

*Thermal cutback*
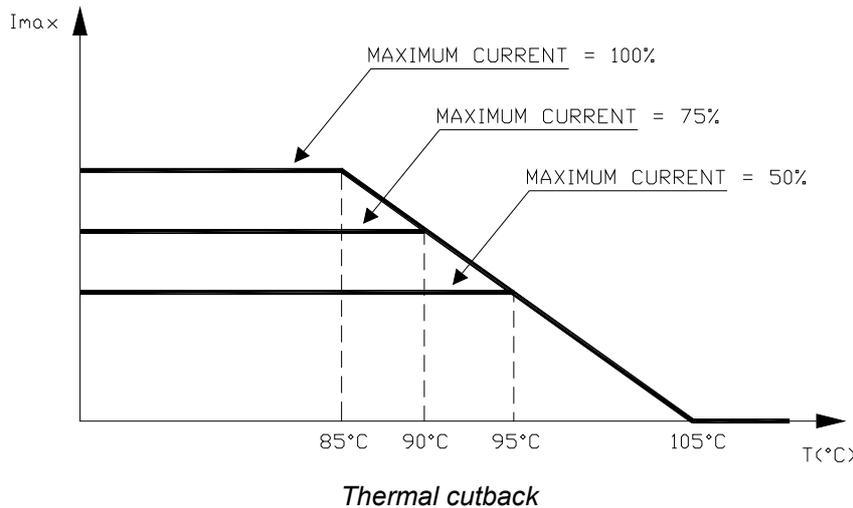
- **External agents**
  The inverter is protected against dust and the spray of liquid to a degree of protection meeting IP65. Nevertheless, it is suggested to carefully study controller installation and position. With little simple shrewdness, the controller protection degree can be strongly increased.
- **Protection against uncontrolled movements**
  The main contactor will not close if:
  - The Power unit is not working.
  - The Logic board doesn't work perfectly.
  - The output voltage of the accelerator does not fall below the minimum voltage value stored, with 1 V added.
  - Running microswitch in closed position.
- **Low battery charge**
  When the battery charge is low, the maximum current is reduced to the half of the maximum current programmed.
- **Protection against accidental start up**
  A precise sequence of operations are necessary before the machine will start. Operation cannot begin if these operations are not carried out correctly. Requests for drive must be made after closing the key switch.

## 6.6.2 Safety Features

⚠️ *ZAPI controllers are designed according to the prEN954-1 specifications for safety related parts of control system and to UNI EN1175-1 norm. The safety of the machine is strongly related to 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. Furthermore, ZAPI is available to develop new SW or HW solutions to improve the safety of the machine, according to customer requirements.*
*Machine manufacturer holds the responsibility for the truck safety features and related approval.*

# 7 START-UP HINTS

## 7.1 Check prior to initial power up

⚠️ *For traction applications, raise up or otherwise disable drives 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 excess pressure build-up (in the event of a pressure relief valve malfunction).*

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

⚠️ *After operation, even with the Key Switch open, the internal capacitors may remain charged for some time. For safe operation, we recommend that the battery is disconnected, and a short circuit is made between Battery Positive and Battery Negative power terminals of the inverter using a Resistor between 10 ohm and 100 ohm.*

Perform the following checks before applying power to a motor controller for the first time:
1. Verify that the proper motor controller for the application has been installed.
2. Verify that the battery voltage matches the motor controller nominal DC supply voltage showed on the product identification label.
3. Verify that the correct software for the application has been loaded.
4. Verify that all power 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 correctly fused for the application. Refer to the vehicle maintenance documentation for the correct fuse size.

## 7.2 Configuring motor controller for the application

Normally, motor controllers shipped for OEM 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 possibly re-programming of the motor controller via the CAN bus.

## 7.3 Set-up procedure for AC traction inverter

This section describes the basic ACE2 set-up procedure using the Zapi Console. When the key switch is closed, if no alarms or errors are present, the Console display shows the standard Zapi opening line.
For the setting of your truck, use the procedure below.
If you need to reply the same setting on different controller, use the SAVE and RESTORE sequence. Remember to re-cycle the key switch if you want to make active any changes to the configuration.

- In ADJUSTMENTS, set BATTERY VOLTAGE according to your set-up.
- Check the wiring and that all commands are functioning. Use the TESTER function to have real-time feedback about their state.
- Perform the accelerator acquisition using the PROGRAM VACC procedure (see paragraph 9.1).
- Set the maximum current for traction and braking 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 the motor thermal sensor adopted.
- Set the acceleration delay (ACCEL MODULATION and ACCEL DELAY parameters). Test the behavior in both directions.
- Set the FREQUENCY CREEP starting from 0.3 Hz. The machine should just move when the drive request is active. Increase the level accordingly.
- Set SPEED REDUCTION as required by your specifications.
- Set the other performance-related parameters such as RELEASE BRAKING, INVERSION BRAKING, DECELERATION BRAKING, PEDAL BRAKING, SPEED LIMIT BRAKING, MAX SPEED FORW, MAX SPEED BACK.
- Make the choice for the truck behavior on a slope (STOP ON RAMP and AUXILIARY TIME parameters).
- Test the truck in all operative conditions (with and without load, on flat and on ramp, etc.).

### 7.3.1 Sin/cos-sensor case

Sin/Cos sensors have a sinusoidal output voltage, with variable amplitude and offset, and normally sin/cos wave has an arbitrary shift with respect to magnetic-field zero position. Offset, amplitude and angle must be set before starting a PM for the first time.
Preliminary settings are the same described above. Plus, an automatic acquisition procedure, embedded in the inverter software, has to be activated only once at commissioning.

Before starting the procedure, be sure that the motor is free to spin, with a minimum load on the shaft:

- In OPTIONS, select ABS SENS. ACQUIRE.
- Select NO at the request of saving data (otherwise the main coil will be opened).
- A message ACQUIRING ABS indicates that the acquisition procedure is ready to start.
- Use the TESTER function to monitor the motor speed for the further steps.
- Activate the TILLER and FW (or BW) microswitches. Motor starts running in open-loop mode.

- Because of the open-loop mode, it is normal if the reported speed is not perfectly stable, but value on display must be, in any case, quite fixed.
- If the motor does not spin, it vibrates or speed on display oscillates too much, stop the acquisition procedure releasing the FW or BW command (see troubleshooting at the paragraph end).
- The first phase, where motor is spinning at low speed (something like 5Hz), allows the Inverter to acquire signal offset and amplitude for both channels.
- After the previous steps are completed, rotor is aligned to the magnetic field origin, and the angle between sin/cos zero value is acquired and stored.
- The next part is a sort of verification when motor is accelerated up to 50 Hz in closed-loop mode.
- Because of the closed loop, the speed reported on display must be stable.
- If something has gone wrong (rotor is not correctly aligned because of friction on the shaft or any other problem), it is possible that rotor starts spinning at uncontrolled speed with high current absorption. The only way to stop it is by switching the inverter off using the key switch.
- When the procedure is correctly completed, the main contactor opens and display shows ACQUIRE END.
- Turn off and then on again the key switch; verify that motor can run according to the accelerator input in both directions.

The inverter goes down the procedure automatically; every phase is marked by a different message on display.

In case of problems, mainly in the first phase, please:
- Check that PM motor pole pairs are set correctly.
- In HARDWARE SETTING increase the ABS.SENS. ACQ.ID parameter (the motor current used for the open-loop phase) so to have more torque and perhaps solve some friction problems (ID RMS MAX must be set congruently).
- If increasing ABS.SENS. ACQ.ID is not enough, increase the ABS.SENS.A.KTETA parameter. It manages the speed in the open-loop phase and in some situations faster speed can help to achieve a more even rotation.

*Offset angle can also be manually refined using the MAN.OFFSET ANGLE parameter. However, the voltage range of the sensor must be first acquired using the automatic procedure.*

## 7.4  Set-up procedure for AC pump inverter

This section describes the basic set-up procedure for the ACE2 inverter in pump configuration. 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 ADJUSTMENT, set BATTERY VOLTAGE according to your set-up (see paragraph 8.2.3).
- Check the wiring and that all commands are functioning. Use the TESTER function to have 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 SET MOT.TEMPERAT according to the type of the motor thermal sensor adopted.
- Set the acceleration delay (ACCEL MODULATION and ACCEL DELAY parameters). Test the behavior in both directions.
- Set the FREQUENCY CREEP starting from 0.3 Hz. The pump should just run when the request is active. Increase the level accordingly.
- Set SPEED REDUCTION as required by your specifications.
- Set the other performance-related parameters such as MAX SPEED LIFT, 1ST SPEED COARSE, 2ND SPEED COARSE, 3RD SPEED COARSE.
- Set hydraulic-steering-related parameters, 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, re-cycle the key switch to make them effective.

# 8 PROGRAMMING & ADJUSTEMENTS

The ACE2 software is powerful and exhaustive, but it is also complex, with a long list of parameters that grant a fine control of all functionalities the inverter can perform. After a deep reading of this section, a well-trained technician or an engineer will be able to understand and modify the parameters.
The procedure to follow in order to modify the parameters could be carried out in four steps:

- Before doing any change save a copy of the default parameters set in the inverter. This procedure is easy to do thanks to the Zapi Smart Console (see section 13.2.11) or thanks to the PC CAN Console (see section 13.1.3).
- 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 changed according to your modifications by reading again the value stored inside the parameters.

To access and adjust all inverter parameters, four possible solutions are available:

- To use the Zapi Console connected to the dedicated flat connector.
- To use the Zapi Smart Console connected to the Can bus line (ask directly to Zapi for the dedicated User Manual)
- To use the PC CAN Console software. This tool is more powerful than the standard serial console. The following paragraphs describe the controller configuration in the case the operator is using Zapi PC CAN console.
- To connect the Zapi Smart Console (or old hand console) through a remote module, like a Zapi tiller card of a Zapi display. This module 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 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 these tools

---

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

---

## 8.1 Settings overview

Inverter settings are defined by a wide set of parameters, organized as follows.

| PARAMETER CHANGE | SET OPTIONS | ADJUSTMENTS | SPECIAL ADJUST. | HARDWARE SETTINGS |
|---|---|---|---|---|
| ACC. TORQUE DEL. | HM DISPLAY OPT. | SET BATTERY | ADJUSTMENT #01 | TOP MAX SPEED |
| DEC. TORQUE DEL. | HM CUSTOM 1 OPT. | ADJUST KEY VOLT. | ADJUSTMENT #02 | CONF.POSITIVE LC |
| ACCELER. DELAY | HM CUSTOM 2 OPT. | ADJUST BATTERY | CURR. SENS. COMP | FEEDBACK SENSOR |
| RELEASE BRAKING | TILL/SEAT SWITCH | SET POSITIVE PEB | DIS.CUR.FALLBACK | TORQUE CONTROL |
| TILLER BRAKING | EB ON TILLER BRK | SET PBRK. MIN | SET CURRENT | ROTATION CW ENC |
| INVERS. BRAKING | BATTERY CHECK | SET PBRK. MAX | SET TEMPERATURE | ROTATION CW MOT |
| DECEL. BRAKING | STOP ON RAMP | MIN LIFT DC | HW BATTERY RANGE | ENCODER PULSES 1 |
| PEDAL BRAKING | PULL IN BRAKING | MAX LIFT DC | PWM AT LOW FREQ | ENCODER PULSES 2 |
| SPEED LIMIT BRK. | SOFT LANDING | MIN LOWER | PWM AT HIGH FREQ | MOTOR P. PAIRS 1 |
| STEER BRAKING | QUICK INVERSION | MAX LOWER | FREQ TO SWITCH | MOTOR P. PAIRS 2 |
| MAX SPEED FORW | PEDAL BRK ANALOG | THROTTLE 0 ZONE | DITHER AMPLITUDE | *** |
| MAX SPEED BACK | HARD & SOFT | THROTTLE X1 MAP | DITHER FREQUENCY | |
| MAX SPEED LIFT | HB ON / SR OFF | THROTTLE Y1 MAP | HIGH ADDRESS | |
| 1ST PUMP SPEED | MAIN POT. TYPE | THROTTLE X2 MAP | CAN BUS SPEED | **HYDRO SETTING** |
| 2ND PUMP SPEED | AUX POT. TYPE | THROTTLE Y2 MAP | EXTENDED FORMAT | HYDRO TIME |
| 3RD PUMP SPEED | SET MOT.TEMPERAT | THROTTLE X3 MAP | DEBUG CANMESSAGE | HYDRO FUNCTION |
| 4TH PUMP SPEED | STEERING TYPE | THROTTLE Y3 MAP | CONTROLLER TYPE | |
| 5TH PUMP SPEED | M.C. FUNCTION | BAT. MIN ADJ. | SAFETY LEVEL | |
| HYD PUMP SPEED | EBRAKE ON APPL. | BAT. MAX ADJ. | RS232 CONSOLLE | |
| CUTBACK SPEED 1 | AUX OUT FUNCTION | BDI ADJ STARTUP | ID CANOPEN OFST | |
| CUTBACK SPEED 2 | SYNCRO | BDI RESET | 2ND SDO ID OFST | |
| H&S CUTBACK | AUTO PARK BRAKE | BATT.LOW TRESHLD | VDC START UP LIM | |
| CTB. STEER ALARM | AUTO LINE CONT. | BAT.ENERGY SAVER | VDC UP LIMIT | |
| CURVE SPEED 1 | ACCEL MODULATION | STEER RIGHT VOLT | VDC START DW LIM | |
| CURVE CUTBACK | EV1 | STEER LEFT VOLT | VDC DW LIMIT | |
| FREQUENCY CREEP | HIGH DYNAMIC | STEER ZERO VOLT | | |
| TORQUE CREEP | INVERSION MODE | MAX ANGLE RIGHT | | |
| MAX. CURRENT TRA | STEER TABLE | MAX ANGLE LEFT | | |
| MAX. CURRENT BRK | WHEELBASE MM | STEER DEAD ANGLE | | |
| ACC SMOOTH | FIXED AXLE MM | STEER ANGLE 1 | | |
| INV SMOOTH | STEERING AXLE MM | STEER ANGLE 2 | | |
| STOP SMOOTH | REAR POT ON LEFT | SPEED FACTOR | | |
| BRK SMOOTH | DISPLAY TYPE | SPEED ON MDI | | |
| STOP BRK SMOOTH | ABS.SENS.ACQUIRE | LOAD HM FROM MDI | | |
| BACKING SPEED | | CHECK UP DONE | | |
| BACKING TIME | | CHECK UP TYPE | | |
| EB. ENGAGE DELAY | | MC VOLTAGE | | |
| AUXILIARY TIME | | MC VOLTAGE RED. | | |
| ROLLING DW SPEED | | EB VOLTAGE | | |
| | | EB VOLTAGE RED. | | |
| | | PWM EV1 | | |
| | | MAX. MOTOR TEMP. | | |
| | | STOP MOTOR TEMP. | | |
| | | A.SENS.MAX SE | | |
| | | A.SENS.MIN SE | | |
| | | A.SENS.MAX CE | | |
| | | A.SENS.MIN CE | | |
| | | MOT.T. T.CUTBACK | | |
| | | VACC SETTING | | |

## 8.2 Settings description

In the following paragraphs, parameters are presented as follows:

| Parameter | Allowable range | Description |
|---|---|---|
| Name of the parameter<br><br>(Availability) | Allowable range of values that can be set.<br><br>(resolution) | Description of the parameter and possibly suggestions on how to set it. |

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

Controller types are coded as:
- **A =** All controller types
- **T =** Traction controller (in single-motor applications)
- **TM =** Traction main controller (in multiple-motor applications)
- **TS =** Traction secondary controller (in multiple-motor applications)
- **P =** AC pump controller
- **CO =** CANopen controller
- **N =** none

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

### 8.2.1 PARAMETER CHANGE

| PARAMETER CHANGE | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **ACC. TORQUE DEL.**<br><br>(T, TM, P, CO) | 0.1 s ÷ 10 s<br><br>(by 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. |
| **DEC. TORQUE DEL.**<br><br>(T, TM, P, CO) | 0.1 s ÷ 10 s<br><br>(by steps of 0.1 s) | This parameter defines the deceleration ramp if TORQUE CONTROL is ON, i.e. the time needed to decrease the torque from the maximum value down to the minimum one. |
| **ACCELER. DELAY**<br><br>(T, TM, P, CO) | 0.1 s ÷ 25.5 s<br><br>(by 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.<br><br>A special software feature manages the acceleration ramp depending on the speed setpoint (see paragraph 9.4). |
| **RELEASE BRAKING**<br><br>(T, TM, P, CO) | 0.1 s ÷ 25.5 s<br><br>(by steps of 0.1 s) | This parameter defines the deceleration ramp performed after the running request is released, i.e. the time needed to decelerate the motor from 100 Hz down to 0 Hz.<br><br>A special software feature manages the deceleration ramp depending on the starting speed (see paragraph 9.4). |

# PARAMETER CHANGE

| Parameter | Allowable range | Description |
|---|---|---|
| **TILLER BRAKING** <br> (T, TM) | 0.1 s ÷ 25.5 s <br><br> (by steps of 0.1 s) | This parameter defines the deceleration ramp performed after the tiller/seat switch is released, i.e. the time needed to decelerate the motor from 100 Hz down to 0 Hz. <br><br> A special software feature manages the deceleration ramp depending on the starting speed (see paragraph 9.4). |
| **INVERS. BRAKING** <br> (T, TM, CO) | 0.1 s ÷ 25.5 s <br><br> (by steps of 0.1 s) | This parameter defines the deceleration ramp performed when the direction switch is toggled during drive, i.e. the time needed to decelerate the motor from 100 Hz down to 0 Hz. <br><br> A special software feature manages the deceleration ramp depending on the starting speed (see paragraph 9.4). |
| **DECEL. BRAKING** <br> (T, TM, CO) | 0.1 s ÷ 25.5 s <br><br> (by steps of 0.1 s) | This parameter defines the deceleration ramp performed when the accelerator is released but not completely, i.e. the time needed to decelerate the motor from 100 Hz down to 0 Hz. <br><br> A special software feature manages the deceleration ramp depending on the starting speed (see paragraph 9.5). |
| **PEDAL BRAKING** <br> (T, TM, CO) | 0.1 s ÷ 25.5 s <br><br> (by steps of 0.1 s) | This parameter defines the deceleration ramp performed when the braking pedal is pressed, i.e. the time needed to decelerate the motor from 100 Hz down to 0 Hz. <br><br> A special software feature manages the deceleration ramp depending on the starting speed (see paragraph 9.5). |
| **SPEED LIMIT BRK.** <br> (T, TM) | 0.1 s ÷ 25.5 s <br><br> (by steps of 0.1 s) | This parameter defines the deceleration ramp performed upon a speed-reduction request, i.e. the time needed to decelerate the motor from 100 Hz down to 0 Hz. <br><br> A special software feature manages the deceleration ramp depending on the starting speed (see paragraph 9.5). |
| **STEER BRAKING** <br> (T, TM) | 0.1 s ÷ 25.5 s <br><br> (by steps of 0.1 s) | This parameter defines the deceleration ramp related to the steering angle, i.e. the time needed to decelerate the motor from 100 Hz down to 0 Hz. <br><br> A special software feature manages the deceleration ramp depending on the starting speed (see paragraph 9.7). |
| **MAX SPEED FORW** <br> (T, TM) | 0% ÷ 100% <br><br> (by 1% steps) | 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><br> (by 1% steps) | This parameter defines the maximum speed in backward direction as a percentage of TOP MAX SPEED. |
| **MAX SPEED LIFT** <br> (P) | 0% ÷ 100% <br><br> (by 1% steps) | 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><br> (by 1% steps) | This parameter defines the speed of the pump motor when 1st speed is requested. It represents a percentage of the maximum pump speed. |
| **2ND PUMP SPEED** <br> (P) | 0% ÷ 100% <br><br> (by 1% steps) | This parameter defines the speed of the pump motor when 2nd speed is requested. It represents a percentage of the maximum pump speed. |

# PARAMETER CHANGE

| Parameter | Allowable range | Description |
|---|---|---|
| **3RD PUMP SPEED** <br> (P) | 0% ÷ 100% <br> (by 1% steps) | 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> (by 1% steps) | 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> (by 1% steps) | This parameter defines the speed of the pump motor when $5^{th}$ speed is requested. It represents a percentage of the maximum pump speed. |
| **HYD PUMP SPEED** <br> (P) | 0% ÷ 100% <br> (by 1% steps) | This parameter defines the speed of the pump motor used for the steering, when HYDRO FUNCTION is ON. It represents a percentage of the maximum pump speed. |
| **CUTBACK SPEED 1** <br> (T, TM, P) | 10% ÷ 100% <br> (by 1% steps) | 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) | 10% ÷ 100% <br> (by 1% steps) | 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% ÷ 100% <br> (by 1% steps) | 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> (by 1% steps) | This parameter defines the maximum traction speed when an alarm from the EPS is read by the microcontroller, 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> (by 1% steps) | 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> (by 1% steps) | 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> (by 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> (255 steps) | This parameter defines the minimum torque applied when torque control is enabled and the forward- or reverse-request switch is closed, but the accelerator is at its minimum. |
| **MAX. CURRENT TRA** <br> (T, TM, P, CO) | 0% ÷ 100% <br> (by 1% steps) | This parameter defines the maximum current applied to the motor during acceleration, as a percentage of the factory-calibrated maximum current. |
| **MAX. CURRENT BRK** <br> (T, TM, P, CO) | 0% ÷ 100% <br> (by 1% steps) | This parameter defines the maximum current applied to the motor during deceleration, as a percentage of the factory-calibrated maximum current. |

## PARAMETER CHANGE

| Parameter | Allowable range | Description |
|---|---|---|
| **ACC SMOOTH**<br>(T, TM, P, CO) | 1 ÷ 5<br>(by 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) | 1 ÷ 5<br>(by 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) | 3 Hz ÷ 100 Hz<br>(by 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) | 1 ÷ 5<br>(by 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) | 3 Hz ÷ 100 Hz<br>(by steps of 1Hz) | This parameter defines the frequency at which the smoothing effect of the deceleration profile ends. |
| **BACKING SPEED**<br>(T, TM) | 0% ÷ 100%<br>(by 1% steps) | 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>(by steps of 0.1 s) | This parameter defines the duration of the inching function. |
| **EB. ENGAGE DELAY**<br>(T, TM, P, CO) | 0 s ÷ 12.75 s<br>(by 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) | 0 s ÷ 10 s<br>(by steps of 0.1 s) | For the encoder version, this parameter defines how long the truck holds in place if the STOP ON RAMP option is ON. |
| **ROLLING DW SPEED**<br>(T, TM, P, CO) | 1 Hz ÷ 50 Hz<br>(by steps of 1Hz) | This parameter defines the maximum speed for the rolling-down function. |

## 8.2.2 SET OPTIONS

| SET OPTIONS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **HM DISPLAY OPT.**<br><br>(T, TM, P, CO) | 0 ÷ 6 | This parameter decides the configuration for the hour meter shown on a display (i.e. MDI). The possible settings are the same of HM CUSTOM 1 OPT. parameter. |
| **HM CUSTOM 1 OPT.**<br><br>(T, TM, P, CO) | 0 ÷ 6 | This parameter decides the configuration for the hour meter number 1 accessible to the customer.<br><br>The possible settings are:<br><br>**0:** The hour meter counts since the controller is on.<br><br>**1:** The hour meter counts when the three-phase power bridge is active.<br><br>**2:** The hour meter counts when the DC motor power bridge is active.<br><br>**3:** The hour meter counts when one of the valve outputs is active.<br><br>**4:** The hour meter counts when the three-phase power bridge is active or the DC motor power bridge is active.<br><br>**5:** The hour meter counts when the DC motor power bridge is active or one of the valve outputs is active.<br><br>**6:** The hour meter counts when the three-phase power bridge is active or the DC motor power bridge is active or one of the valve outputs is active.<br><br>**Note: options 2, 4, 5 and 6 are not effective on ACE2** |
| **HM CUSTOM 2 OPT.**<br><br>(T, TM, P, CO) | 0 ÷ 6 | This parameter decides the configuration for the hour meter number 2 accessible to the customer. The possible settings are the same of HM CUSTOM 1 OPT. parameter. |
| **TILL/SEAT SWITCH**<br><br>(T, TM, P) | HANDLE ÷ SEAT | This option handles the input A6. This input opens when the operator leaves the truck. It is connected to a key voltage when the operator is present.<br><br>**HANDLE =** input A6 is managed as tiller input (no delay when released).<br><br>**DEADMAN =** input A6 is managed as dead-man input (no delay when released).<br><br>**SEAT =** input A6 is managed as seat input (with a delay when released and the de-bouncing function). |
| **EB ON TILLER BRK**<br><br>(T) | OFF, ON | This option defines how the electromechanical brake is managed depending on the status of tiller/seat input:<br><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><br>**OFF =** when the tiller input goes into OFF state, the "tiller braking" ramp is applied before engaging the electromechanical brake. |

| SET OPTIONS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **BATTERY CHECK**<br><br>(T, TM, P, CO) | 0 ÷ 3 | This option specifies the management of the low battery charge situation. There are four levels of intervention:<br><br>**0 =** nothing happens; the battery charge level is evaluated but ignored, meaning that no action is taken when the battery runs out.<br><br>**1 =** the BATTERY LOW alarm occurs when the battery level is evaluated to be lower or equal to 10% of the full charge. With the BATTERY LOW alarm, the control reduces the maximum speed down to 24% of the full speed and it also reduces the maximum current down to 50% of the full current.<br><br>**2 =** the BATTERY LOW alarm occurs when the battery level is evaluated to be lower or equal to 10% of the full charge.<br><br>**3 =** the BATTERY LOW alarm occurs when the battery level is evaluated to be lower or equal to 10% of the full charge. With the BATTERY LOW alarm, the control reduces the maximum speed down to 24% of the full speed. |
| **STOP ON RAMP**<br><br>(T, TM, P, CO) | OFF, ON | This parameter enables or disables the stop-on-ramp feature (the truck is electrically held in place on a slope for a defined time).<br><br>**ON =** the stop-on-ramp feature is performed for a time set in the AUXILIARY TIME parameter.<br><br>**OFF =** the stop-on-ramp feature is not performed. Instead, a controlled slowdown is performed for a minimum time set in the AUXILIARY TIME parameter.<br><br>After the AUXILIARY TIME interval, the three-phase bridge is released and, if present, the electromechanical brake activated (see parameter AUX OUT FUNCTION). |
| **PULL IN BRAKING**<br><br>(A) | OFF, ON | This parameter enables or disables the functionality that continues to give torque even if the traction (or lift) request has been released.<br><br>**ON =** when the operator releases the traction request, the inverter keeps running the truck, as to oppose the friction that tends to stop it. Similarly, in pump applications, when the operator releases the lift request, the inverter keeps running the pump avoiding the unwanted descent of the forks.<br><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 by 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><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. If the rise is steep, the truck may stop fast and may also go backwards in short time, possibly leading to a dangerous situation.<br><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) | NONE ÷ BELLY | This parameter defines the quick-inversion functionality.<br><br>**NONE =** the quick-inversion function is not managed.<br><br>**BRAKE =** upon a quick-inversion request, the motor is braked.<br><br>**TIMED =** the quick-inversion function is timed: upon a QI request the controller drives the motor in the opposite direction for a fixed time (1.5 seconds by default).<br><br>**BELLY =** the quick-inversion function is managed but not timed: upon a QI request the controller drives the motor in the opposite direction until the request is released. |
| **PEDAL BRK ANALOG**<br>(T, TM) | OFF, ON | This parameter defines the kind of brake pedal adopted.<br><br>**ON =** brake pedal outputs an analog signal, braking is linear.<br><br>**OFF =** brake pedal outputs a digital signal, braking is on/off. |
| **HARD & SOFT**<br>(T, TM) | OFF, ON | This parameter enables or disables the Hard-and-Soft functionality. With H&S, it is possible to start the truck (at reduced speed) only by activating the H&S switch and the accelerator, without the tiller input.<br><br>**ON =** H&S function is enabled<br><br>**OFF =** H&S function is disabled<br><br>**Note: by default this function is not present on ACE2.** |
| **HB ON / SR OFF**<br>(T, TM) | OFF, ON | This parameter defines the function associated with input A3.<br><br>**ON =** Handbrake.<br><br>**OFF =** Speed reduction. |

| SET OPTIONS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **MAIN POT. TYPE**<br><br>(T, TM) | 0 ÷ 11 | This parameter defines the type of the main potentiometer connected to A3 contact.<br><br>**0:** V-type pot, low to high value, with direction switches, without enable switch, without enable dead band.<br><br>**1:** V-type pot, low to high value, with direction switches, without enable switch, with enable dead band.<br><br>**2:** V-type pot, high to low value, with direction switches, without enable switch, without enable dead band.<br><br>**3:** V-type pot, high to low value, with direction switches, without enable switch, with enable dead band.<br><br>**4:** Z-type pot, low to high value, with direction switches, without enable switch, without enable dead band.<br><br>**5:** Z-type pot, low to high value, with direction switches, without enable switch, with enable dead band.<br><br>**6:** Z-type pot, low to high value, without direction switches, with enable switch, with enable dead band<br><br>**7:** Z-type pot, low to high value, without direction switches, without enable switch, with enable dead band.<br><br>**8:** Z-type pot, high to low value, with direction switches, without enable switch, without enable dead band.<br><br>**9:** Z-type pot, high to low value, with direction switches, without enable switch, with enable dead band.<br><br>**10:** Z-type pot, high to low value, without direction switches, with enable switch, with enable dead band.<br><br>**11:** Z-type pot, high to low value, without direction switches, without enable switch, with enable dead band. |
| **AUX POT. TYPE**<br><br>(T, TM, TS, P) | 0 ÷ 15 | This parameter defines the type of the auxiliary potentiometer connected to A10 contact.<br><br>**0 ÷ 11:** Same as MAIN POT. TYPE, see prev. parameter.<br><br>**12:** No pot, with direction switches, with enable switch<br><br>**15:** No pot, with direction switches, without enable switch |

## SET OPTIONS

| Parameter | Allowable range | Description |
|---|---|---|
| **SET MOT.TEMPERAT**<br>(T, TM, P, CO) | NONE ÷ OPTION#3 | This parameter defines the type of motor temperature sensor adopted.<br><br>**NONE =** no motor thermal sensor is connected.<br><br>**DIGITAL =** a digital (ON/OFF) motor thermal sensor is connected to A23.<br><br>**OPTION#1 =** an analog motor thermal sensor is connected to A23. The temperature sensor is a KTY 84-130 PTC (positive thermal coefficient resistance).<br><br>**OPTION#2 =** an analog motor thermal sensor is connected to A23. The temperature sensor is a KTY 83-130 PTC (positive thermal coefficient resistance).<br><br>**OPTION#3 =** an analog motor thermal sensor is connected to A23. The temperature sensor is a PT1000 PTC (positive thermal coefficient resistance). |
| **STEERING TYPE**<br>(T, TM) | NONE ÷ ANALOG | This parameter defines which type of steering unit is connected to the controller.<br><br>**NONE =** steering module is not present on the truck; ACE2 does not wait for any CAN message from the EPS and it does not apply EPS and braking steering cutback.<br><br>**OPTION#1 =** EPS is present and it is configured with encoder + toggle switches, whose signals are acquired and related data transmitted to ACE2 via CAN bus.<br><br>**OPTION#2 =** EPS is present and it is configured with potentiometer + encoder, whose signals are acquired and related data transmitted to ACE2 via CAN bus.<br><br>**ANALOG =** A hydraulic steering is adopted and ACE2 acquires through one of its analog inputs the signal coming from a steering potentiometer, as a feedback of the steering orientation. |
| **M.C. FUNCTION**<br>(T, TM, P, CO) | OFF ÷ OPTION#2 | This parameter defines the configuration for the main contactor or line contactor output (A16, NLC: Negative Line Contactor).<br><br>**OFF =** main contactor is not present. Diagnoses are masked and MC is not driven.<br><br>**ON =** main contactor is in standalone configuration. Diagnoses are performed and MC is closed after key-on only if they have passed.<br><br>**OPTION#1 =** for a traction & pump setup, with only one main contactor for both controllers. Diagnoses are performed and MC is closed after key-on only if they have passed.<br><br>**OPTION#2 =** for a traction & pump setup, with two main contactors. Each controller drives its own MC. Diagnoses are performed and MCs are closed after key-on only if they have passed. |
| **EBRAKE ON APPL.**<br>(T, TM, P, CO) | ABSENT, PRESENT | This parameter defines whether the application includes an electromechanical brake or not. |

| SET OPTIONS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **AUX OUT FUNCTION**<br><br>(A) | NONE, BRAKE | This parameter enables or disables the output NEB A18, dedicated to the electromechanical brake:<br><br>**NONE =** diagnoses are masked and E.B. is not driven upon a traction request.<br><br>**BRAKE =** E.B. is driven upon a traction request if all the related diagnoses pass. The behavior on a slope depends on the STOP ON RAMP setting. **Do not use this setting if the electromechanical brake is not really present.**<br><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. . |
| **SYNCRO**<br><br>(CO) | OFF, ON | This parameter enables or disables the syncro message.<br><br>**OFF =** the syncro message is not used.<br><br>**ON =** the syncro message is enabled. |
| **AUTO PARK BRAKE**<br><br>(CO) | OFF, ON | This parameter enables or disables the autonomous management of the brake.<br><br>**OFF =** E.B. is activated or deactivated according to the signal received via CAN bus.<br><br>**ON =** E.B. is managed by the controller itself ignoring any activation/deactivation signal received via CAN bus. |
| **AUTO LINE CONT.**<br><br>(CO) | OFF, ON | This parameter enables or disables the autonomous management of the main contactor.<br><br>**OFF =** main contactor is opened or closed according to the signals received by CAN bus.<br><br>**ON =** main contactor is managed by the controller itself ignoring any activation/deactivation signal received via CAN bus. |
| **ACCEL MODULATION**<br><br>(T, TM, P, CO) | OFF, ON | This parameter enables or disables the acceleration-modulation function.<br><br>**OFF =** the acceleration rate is inversely proportional to the ACCEL DELAY parameter.<br><br>**ON =** the acceleration ramp is inversely proportional to the ACCEL 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 ACCEL DELAY.<br><br>See paragraph 9.4. |

| SET OPTIONS | | |
| --- | --- | --- |
| **Parameter** | **Allowable range** | **Description** |
| **EV1**<br><br>(A) | ABSENT ÷ OPTION#2 | This parameter defines how the output A9 (NAUX1) operates.<br><br>**ABSENT =** output not enabled, no load on A9.<br><br>**OPTION#1 =** A9 manages an on/off valve. By default it is controlled by input A10.<br><br>**OPTION#2 =** Not used option.<br><br>**OPTION#3 =** A9 manages a horn. By default it is controlled by input A10.<br><br>**OPTION#4 =** A9 manages a load activated when an alarm occurs. |
| **HIGH DYNAMIC**<br><br>(T, TM, P, CO) | OFF, ON | This parameter enables or disables the high-dynamic function.<br><br>**ON =** all acceleration and deceleration profiles set by dedicated parameters are ignored and the controller works always with maximum performance.<br><br>**OFF =** standard behavior. |
| **INVERSION MODE**<br><br>(T, TM) | OFF, ON | This parameter defines the behavior of the Quick-Inversion input A6.<br><br>**ON =** the Quick-Inversion switch is normally closed (function is active when the switch is open).<br><br>**OFF =** the Quick-Inversion switch is normally open (function is active when the switch is closed). |
| **STEER TABLE**<br><br>(TM) | NONE ÷ OPTION#2 | This parameter defines the steering table.<br><br>**NONE =** T he 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><br>**OPTION#1 =** Three-wheels predefined steering table.<br><br>**OPTION#2 =** Four-wheels predefined steering table.<br><br>**The steering table depends on truck geometry. The two available options by default may not fit the requirements of your truck. It is advisable to store the dimensions of the truck in the parameters listed above in order to create a custom steering table.**<br><br>**It is strongly recommended to consult paragraph 9.7 in order to properly understand how to fill the mentioned parameters. If the steering performance of the truck does not match your requirements even after you have entered the right truck dimensions, contact a Zapi technician in order to determine if a custom steering table has to be created.** |
| **WHEELBASE MM**<br><br>(TM) | 0 ÷ 32000 | This parameter must be filled with the wheelbase, i.e. the distance between the two axles of the truck, expressed in millimeters.<br><br>See paragraph 9.7. |

| SET OPTIONS | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **FIXED AXLE MM** <br><br>(TM) | 0 ÷ 32000 | This parameter must be filled with the axle width at which the non-steering wheels are connected, expressed in millimeters. <br><br>See paragraph 9.7 |
| **STEERING AXLE MM** <br><br>(TM) | 0 ÷ 32000 | This parameter must be filled with the axle length at which the steering wheels are connected. The length must be expressed in millimeters. <br><br>See paragraph 9.7 |
| **REAR POT ON LEFT** <br><br>(TM) | OFF, ON | This parameter defines the position of the steering potentiometer. <br><br>**OFF =** the steering potentiometer is not placed on the rear-left wheel. <br><br>**ON =** the steering potentiometer is placed on the rear-left wheel. |
| **DISPLAY TYPE** <br><br>(T, TM, P) | 0 ÷ 9 | This parameter defines which type of display is connected to the inverter. <br><br>**0 =** none. <br><br>**1 =** MDI PRC. <br><br>**2 =** ECO DISPLAY. <br><br>**3 =** SMART DISPLAY. <br><br>**4 =** MDI CAN. <br><br>**5 ÷ 9 =** available for future developments. |
| **ABS.SENS.ACQUIRE** <br><br>(A – Only custom HW with sin/cos) | OFF, ON | This parameter activates the acquisition of motor speed sensor used for PMSM (Permanent-Magnets Synchronous Motor). <br><br>**Contact Zapi Technicians for a detailed description of the acquisition procedure.** |

⚠️  *Ensure the negative brake is installed and functioning before driving the truck on any slope.*

⚠️  *Driving the truck on a slope without the brake functioning may lead to serious accidents for the operators and surrounding people.*

## 8.2.3  ADJUSTMENT

| ADJUSTMENT | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **SET BATTERY** (A) | 24V ÷ 96V | This parameter defines the nominal battery voltage. The available options are: **36V, 48V, 72V, 80V, 96V** |
| **ADJUST KEY VOLT.** (A) | | Fine adjustment of the key voltage measured by the controller. Calibrated by Zapi production department during the end of line test. |
| **ADJUST BATTERY** (A) | Volt | Fine adjustment of the battery voltage measured by the controller. Calibrated by Zapi production department during the end of line test. |
| **SET POSITIVE PEB** (A) | 12V ÷ 96V | This parameter defines the supply-voltage feeding  pin PCOM (A17). The available values are: **12V, 24V, 36V, 40V, 48V, 72V, 80V, 96V** |
| **SET PBRK. MIN** (T, TM, TS, CO) | 0V ÷ 25.5V (by steps of 0.1V) | It records the minimum value of brake potentiometer when the brake is analog. |
| **SET PBRK. MAX** (T, TM, TS, CO) | 0V ÷ 25.5V (by steps of 0.1V) | It records the maximum value of brake potentiometer when the brake is analog. |
| **MIN LIFT DC** **(Read Only)** (T, TM, TS, P) | 0V ÷ 25.5V (by steps of 0.1V) | It records the minimum value of lifting potentiometer when the lift switch is closed. See paragraph 9.2 |
| **MAX LIFT DC** **(Read Only)** (T, TM, TS, P) | 0V ÷ 25.5V (by steps of 0.1V) | It records the maximum value of lifting potentiometer when the lift switch is closed. See paragraph 9.2 |
| **MIN LOWER** **(Read Only)** (T, TM, TS, P) | 0V ÷ 25.5V (by steps of 0.1V) | It records the minimum value of lower potentiometer when the lower switch is closed. See paragraph 9.2 |
| **MAX LOWER** **(Read Only)** (T, TM, TS, P) | 0V ÷ 25.5V (by steps of 0.1V) | It records the maximum value of lower potentiometer when the lower switch is closed. See paragraph 9.2 |
| **THROTTLE 0 ZONE** (T, TM, P) | 0% ÷ 100% (by 1% steps) | This parameter defines a dead band in the accelerator input curve. See paragraph 9.8 |
| **THROTTLE X1 MAP** (T, TM, P) | 0% ÷ 100% (by 1% steps) | This parameter defines the accelerator input curve. See paragraph 9.8 |
| **THROTTLE Y1 MAP** (T, TM, P) | 0% ÷ 100% (by 1% steps) | This parameter defines the accelerator input curve. See paragraph 9.8 |

| ADJUSTMENT | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **THROTTLE X2 MAP**<br>(T, TM, P) | 0% ÷ 100%<br>(by 1% steps) | This parameter defines the accelerator input curve.<br>See paragraph 9.8 |
| **THROTTLE Y2 MAP**<br>(T, TM, P) | 0% ÷ 100%<br>(by 1% steps) | This parameter defines the accelerator input curve.<br>See paragraph 9.8 |
| **THROTTLE X3 MAP**<br>(T, TM, P) | 0% ÷ 100%<br>(by 1% steps) | This parameter defines the accelerator input curve.<br>See paragraph 9.8 |
| **THROTTLE Y3 MAP**<br>(T, TM, P) | 0% ÷ 100%<br>(by step of 1%) | This parameter defines the accelerator input curve.<br>See paragraph 9.8 |
| **BAT. MIN ADJ.**<br>(T, TM, P, CO) | -12.8% ÷ 12.7%<br>(by steps of 0.1%) | This parameter defines the minimum level of the battery-discharge table. It is used to calibrate the discharge algorithm for the adopted battery.<br>See paragraph 9.10 |
| **BAT. MAX ADJ.**<br>(T, TM, P, CO) | -12.8% ÷ 12.7%<br>(by steps of 0.1%) | This parameter defines the maximum level of the battery-discharge table. It is used to calibrate the discharge algorithm for the adopted battery.<br>See paragraph 9.10 |
| **BDI ADJ STARTUP**<br>(T, TM, P, CO) | -12.8% ÷ 12.7%<br>(by steps of 0.1%) | This parameter defines the start-up level of the battery-charge table, in order to evaluate the battery charge at key-on.<br>See paragraph 9.10 |
| **BDI RESET**<br>(T, TM, P, CO) | 0% ÷ 100%<br>(by 1% steps) | This parameter defines the minimum variation of the battery-discharge table to update the battery percentage at start-up. It is used to calibrate the discharge algorithm for the adopted battery.<br>See paragraph 9.10 |
| **BATT.LOW TRESHLD**<br>(T, TM, P, CO) | 1% ÷ 50%<br>(by 1% steps) | This parameter defines the minimum charge percentage under which the BATTERY LOW alarm rises. |
| **BAT.ENERGY SAVER**<br>(A) | OFF, ÷ ON | When this parameter is ON, the control saves the battery charge when it is below a certain charge threshold, through a motor-torque reduction. |
| **STEER RIGHT VOLT**<br>(T,TM) | 0V ÷ 25.5V<br>(by steps of 0.1V) | This parameter records the maximum steering-control voltage while turning right.<br>See paragraph 9.3 |
| **STEER LEFT VOLT**<br>(T,TM) | 0V ÷ 25.5V<br>(by steps of 0.1V) | This parameter records the maximum steering-control voltage while turning left.<br>See paragraph 9.3 |
| **STEER ZERO VOLT**<br>(T,TM) | 0V ÷ 25.5V<br>(by steps of 0.1V) | This parameter records the maximum steering-control voltage when it is in the straight-ahead position<br>See paragraph 9.3 |

| ADJUSTMENT | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **MAX ANGLE RIGHT** (T,TM) | 0° ÷ 90° (by steps of 1°) | This parameter defines the maximum steering-wheel angle while turning right. |
| **MAX ANGLE LEFT** (T,TM) | 0° ÷ 90° (by steps of 1°) | This parameter defines the maximum steering-wheel angle while turning left. |
| **STEER DEAD ANGLE** (T, TM) | 1° ÷ 50° (by steps of 1°) | This parameter defines the maximum steering-wheel angle up to which the permitted traction speed is 100%. See paragraph 9.7 |
| **STEER ANGLE 1** (T, TM) | 1° ÷ 90° (by steps of 1°) | This parameter defines the steering-wheel angle at which traction speed is reduced to the value imposed by CURVE SPEED 1. For steering-wheel angles between STEER DEAD ANGLE and STEER ANGLE 1, traction speed is reduced linearly from 100% to CURVE SPEED 1. See paragraph 9.7 |
| **STEER ANGLE 2** (T, TM) | 1° ÷ 90° (by steps of 1°) | This parameter defines the steering-wheel angle beyond which traction speed is reduced to CURVE CUTBACK. For steering-wheel angles between STEER ANGLE1 and STEER ANGLE 2 traction speed is reduced linearly from CURVE SPEED 1 to CURVE CUTBACK. See paragraph 9.7 |
| **SPEED FACTOR** (T, TM, CO) | 0 ÷ 255 | This parameter defines the coefficient used for evaluating the truck speed (in km/h) from the motor frequency (in Hz), according to the following formula: $$Speed\ [km/h] = 10 \cdot \frac{frequency\ [Hz]}{Speed\ factor}$$ |
| **SPEED ON MDI** (T, TM, CO) | OFF, ON | This parameter enables or disables the speed visualization on MDI display: **ON =** MDI shows traction speed when the truck is moving. In steady-state condition the speed indication is replaced by the hour-meter indication. **OFF =** Standard MDI functionality. |
| **LOAD HM FROM MDI** (T, TM, P, CO) | OFF, ON | This parameter enables or disables the transfer of the hour-meter to a MDI unit. **OFF =** controller hour meter is not transferred and recorded on the MDI hour meter. **ON =** controller hour meter is transferred and recorded on the MDI hour meter (connected via the Serial Link). |
| **CHECK UP DONE** (T, TM, P, CO) | OFF, ON | In order to cancel the CHECK UP NEEDED warning, set this parameter ON after the required maintenance service. |

| ADJUSTMENT | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **CHECK UP TYPE**<br><br>(T, TM, P, CO) | NONE ÷ OPTION#3 | This parameter defines the CHECK UP NEEDED warning:<br><br>**NONE =** no CHECK UP NEEDED warning.<br><br>**OPTION#1 =** CHECK UP NEEDED warning shown on the hand-set and MDI after 300 hours.<br><br>**OPTION#2 =** like OPTION#1, plus speed reduction intervenes after 340 hours.<br><br>**OPTION#3 =** like OPTION#2, plus the truck definitively stops after 380 hours. |
| **MC VOLTAGE**<br><br>(A) | 0% ÷ 100%<br><br>(by 1% steps) | This parameter specifies the duty-cycle ($t_{ON}/T_{PWM}$) of the PWM applied to the main-contactor output (A16) during the first second after the activation signal that causes the main contactor to close. |
| **MC VOLTAGE RED.**<br><br>(A) | 0% ÷ 100%<br><br>(by 1% steps) | 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><br>For details and examples see paragraph 9.9 |
| **EB VOLTAGE**<br><br>(A) | 0% ÷ 100%<br><br>(by 1% steps) | This parameter specifies the duty-cycle ($t_{ON}/T_{PWM}$) of the PWM applied to the main-contactor output (A18) during the first second after the activation signal that causes the electromechanical brake to release. |
| **EB VOLTAGE RED.**<br><br>(A) | 0% ÷ 100%<br><br>(by 1% steps) | This parameter defines a percentage of EB VOLTAGE parameter and it determines the duty-cycle applied after the first second since when the electromechanical brake is released.<br><br>For details and examples see paragraph 9.9 |
| **PWM EV1**<br><br>(A) | 0% ÷ 100%<br><br>(255 steps) | This parameter defines the duty-cycle of the PWM applied to AUX output (A9). |
| **MAX. MOTOR TEMP.**<br><br>(T, TM, P, CO) | 60°C ÷ 175°C<br><br>(by steps of 1°C) | This parameter defines the motor temperature above which a 50% cutback is applied to the maximum current. Cutback is valid only during motoring, while during braking the 100% of the maximum current is always available independently by the temperature. |
| **STOP MOTOR TEMP.**<br><br>(T, TM, P, CO) | 60°C ÷ 190°C<br><br>(by steps of 1°C) | This parameter defines the maximum motor temperature permitted, above which the controller stops driving the motor. |
| **A.SENS.MAX SE**<br><br>(A – Only sin/cos customized HW) | Volt | This parameter records the maximum offset voltage at the sine analog input during the auto-teaching procedure.<br><br>It can be compared with the A.SENS.OFFSET SR entry value. |
| **A.SENS.MIN SE**<br><br>(A – Only sin/cos customized HW) | Volt | This parameter records the minimum offset voltage at the sine analog input during the auto-teaching procedure.<br><br>It can be compared with the A.SENS.OFFSET SR entry value. |

| ADJUSTMENT | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **A.SENS.MAX CE** <br><br> (A – Only sin/cos customized HW) | Volt | This parameter records the maximum offset voltage at the cosine analog input during the auto-teaching procedure. <br><br> It can be compared with the A.SENS.OFFSET CR entry value. |
| **A.SENS.MIN CE** <br><br> (A – Only sin/cos customized HW) | Volt | This parameter records the minimum offset voltage at the cosine analog input during the auto-teaching procedure**.** <br><br> It can be compared with the A.SENS.OFFSET CR entry value. |
| **MOT.T. T.CUTBACK** <br><br> (A) | OFF, ON | When this parameter is ON, the control linearly reduces the motor torque basing on the motor temperature. Reference limits of the linear reduction are MAX MOTOR TEMP and TEMP. MOT. STOP. |
| **VACC SETTING** <br><br> (A) | Volt | See the PROGRAM VACC procedure in paragraphs 13.1.4 and 13.2.6. |

## 8.2.4 SPECIAL ADJUST.

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

| SPECIAL ADJUST. | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **ADJUSTMENT #01** <br> **(Read Only)** <br> (A) | by 1% steps) | Gain of the first traction-motor current-sensing amplifier. |
| **ADJUSTMENT #02** <br> **(Read Only)** <br> (A) | by 1% steps) | Gain of the second traction-motor current-sensing amplifier. <br><br> NOTE: only Zapi technicians can change this value through a special procedure. |
| **CURR. SENS. COMP** <br><br> (A) | OFF, ON | This parameter enables or disables the linear compensation for the current sensors. <br><br> NOTE: only Zapi technicians can change this value through a special procedure. |
| **DIS.CUR.FALLBACK** <br><br> (A) | OFF, ON | This parameter disables or enables current reduction (applied after one minute of traction). <br><br> **ON =** current reduction is disabled. <br><br> **OFF =** current reduction is enabled. |

| | SPECIAL ADJUST. | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **SET CURRENT**<br>**(Read Only)**<br>(A) | 450A ÷ 650A | This parameter defines the nominal maximum current that the inverter can provide to the motor, in $A_{RMS}$.<br>The available values are indicated at the chapter: |
| **SET TEMPERATURE**<br>(A) | 0°C ÷ 255°C<br>(by 1°C steps) | This parameter calibrates the controller-temperature reading. |
| **HW BATTERY RANGE**<br>**(Read Only)**<br>(T, TM, P, CO) | 0 ÷ 3 | This parameter defines the battery voltage range.<br>NOTE: only Zapi technicians can change this value. |
| **PWM AT LOW FREQ**<br>(A) | | 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) | | 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) | Volt | (Factory adjusted). This parameter defines the electrical frequency at which the switching frequency is changed from PWM AT LOW FREQ to PWM AT HIGH FREQ. |
| **DITHER AMPLITUDE**<br>(A) | 0% ÷ 13% | This parameter defines the dither signal amplitude. The dither signal is a square wave added to the proportional-valve set-point. In this way the response to set-point variations results optimized. This parameter is a percentage of the valve maximum current. Setting the parameter to 0% means the dither is not used.<br>The available values are:<br>**0.0%, 1.0%, 2.5%, 4.0%, 5.5%, 7.0%, 8.5%, 10%, 11.5%, 13.0%** |
| **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** |
| **HIGH ADDRESS**<br>(A) | 0 ÷ 4 | This parameter is used to access special memory addresses. |
| **CAN BUS SPEED**<br>(A) | 20 kbps ÷ 500 kbps | This parameter defines the CAN bus data-rate in kbps.<br>**20, 50, 125, 250, 500** |
| **EXTENDED FORMAT**<br>(A) | OFF, ON | This parameter defines the CAN bus protocol. |
| **DEBUG CANMESSAGE**<br>(A) | OFF, ON | This parameter enables or disables special debug messages. |

| SPECIAL ADJUST. | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **CONTROLLER TYPE**<br><br>(A) | 0 ÷ 15 | This parameter defines the controller type:<br><br>**0 =** Traction AC<br><br>**1 =** Pump AC<br><br>**2 =** CAN OPEN AC<br><br>**3 =** Dual traction AC (master)<br><br>**4 =** Dual traction AC (slave)<br><br>**5 =** Traction brushless<br><br>**6 =** Pump brushless<br><br>**7 =** CAN OPEN brushless<br><br>**8 =** Dual traction brushless (master)<br><br>**9 =** Dual traction brushless (slave)<br><br>**10 =** Multi-motor traction AC (slave 2)<br><br>**11 =** Multi-motor traction AC (slave 3)<br><br>**12 =** Multi-motor traction brushless (slave 2)<br><br>**13 =** Multi-motor traction brushless (slave 3)<br><br>**14 =** Gen. set AC (slave 2)<br><br>**15 =** Gen. set brushless (slave 3)<br><br>**NOTE:** a mismatch between this parameter and the hardware configuration may lead to a severe malfunctioning of the controller. |
| **SAFETY LEVEL**<br><br>(T, TM, P, CO) | 0 ÷ 3 | This parameter defines the safety level of the controller, i.e. the functionality of the supervisor microcontroller.<br><br>**0 =** supervisor µC does not check any signal.<br><br>**1 =** supervisor µC checks the inputs and the outputs.<br><br>**2 =** supervisor µC checks the inputs and the motor set-point.<br><br>**3 =** supervisor µC checks the inputs, the outputs and the motor set-point. |
| **RS232 CONSOLLE**<br><br>(A) | OFF ÷ ON | This parameter enables or disables the console to change settings.<br><br>NOTE: only Zapi technicians can change this value. |
| **ID CANOPEN OFST**<br><br>(CO) | 0 ÷ 56<br><br>(by steps of 8) | This parameter defines the offset of the CANopen frame IDs. |
| **2ND SDO ID OFST**<br><br>(A) | 0 ÷ 126<br><br>(by 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><br>(T, TM, P, CO) | by 1% steps) | This parameter defines the battery voltage (as percentage of the nominal voltage) above which delivered power is reduced in order to avoid an overvoltage condition during braking. |

## SPECIAL ADJUST.

| Parameter | Allowable range | Description |
| --- | --- | --- |
| **VDC UP LIMIT** <br> (T, TM, P, CO) | 0% ÷ 255% <br> (by 1% steps) | This parameter defines the battery voltage (as percentage of the nominal voltage) above which the inverter stops and gives a LOGIC FAILURE #1 alarm in order to avoid a damaging overvoltage condition. |
| **VDC START DW LIM** <br> (T, TM, P, CO) | 0% ÷ 255% <br> (by 1% steps) | This parameter defines the battery voltage (as percentage of nominal voltage) below which delivered power is reduced in order to avoid an undervoltage condition (typically during accelerations with low battery). |
| **VDC DW LIMIT** <br> (T, TM, P, CO) | 0% ÷ 255% <br> (by 1% steps) | This parameter defines the battery voltage (as percentage of nominal voltage) below which the inverter stops and gives a LOGIC FAILURE #3 alarm in order to avoid an uncontrolled shutdown due to an undervoltage condition. |

### 8.2.5  HARDWARE SETTINGS

The HARDWARE SETTINGS parameters group includes the motor-control-related parameters. Only those parameters the user can modify are here described.

*For descriptions and teaching about missing parameters contact a Zapi technician.*

## HARDWARE SETTINGS

| Parameter | Allowable range | Description |
| --- | --- | --- |
| **TOP MAX SPEED** <br> (T, TM, P, CO) | 0 Hz ÷ 600 Hz <br> (by steps of 10 Hz) | (Factory adjusted). This parameter defines the maximum motor speed. |
| **CONF.POSITIVE LC** <br> (A) | 0 ÷ 2 | (Factory adjusted). NOTE: only Zapi technicians can change this value through a special procedure. This parameter defines the positive supply configuration for the main-contactor coil. <br><br> **0 =** it is connected to PCOM (A17) <br> **1 =** it is connected to KEY (A1) <br> **2 =** it is connected to SEAT input (A6) |
| **FEEDBACK SENSOR** <br> (A) | 0 ÷ 4 | (Factory adjusted). This parameter defines the type of the adopted speed sensor. <br><br> **0 =** incremental encoder <br> **1 =** sin/cos sensor <br> **2 =** incremental encoder + sin/cos sensor <br> **3 =** incremental encoder + sin/cos sensor + index <br> **4 =** PWM absolute sensor + incremental encoder + index <br> **5 =** resolver |

## HARDWARE SETTINGS

| Parameter | Allowable range | Description |
| --- | --- | --- |
| **TORQUE CONTROL**<br><br>(A) | OFF, ON | This parameter defines the type of control algorithm performed by the inverter.<br><br>**OFF =** speed control is performed; accelerator input is interpreted as the speed reference.<br><br>**ON =** torque control is performed; accelerator input is interpreted as the torque reference.<br><br>For details see paragraphs 6.4 and 6.5. |
| **ROTATION CW ENC**<br><br>(A) | OPTION#1, OPTION#2 | This parameter defines the configuration of the encoder.<br><br>**OPTION#1 =** channel A anticipates channel B<br><br>**OPTION#2 =** channel B anticipates channel A |
| **ROTATION CW MOT**<br><br>(A) | OPTION#1, OPTION#2 | (Factory adjusted). This parameter defines the sequence of the motor. The available values are: phases.<br><br>**OPTION#1 =** U-V-W corresponds to forward direction.<br><br>**OPTION#2 =** V-U-W corresponds to forward direction. |
| **ENCODER PULSES 1**<br><br>(T, TM, P, CO) | 32 ÷ 1024 | This parameter defines the number of encoder pulses per revolution. It must be set equal to ENCODER PULSES 2; otherwise the controller raises an alarm.<br><br>The available options are:<br><br>    **32, 48, 64, 80, 64, 128, 256, 512, 1024**<br><br>**NOTE: with standard HW the capability to use encoders with high number of pulses could be limited depending on the speed. Ask to Zapi technicians before changing this parameter.** |
| **ENCODER PULSES 2**<br><br>(T, TM, P, CO) | 32 ÷ 1024 | This parameter defines the number of encoder pulses per revolution. It must be set equal to ENCODER PULSES 1; otherwise the controller raises an alarm.<br><br> The available options are:<br><br>    **32, 48, 64, 80, 64, 128, 256, 512, 1024**<br><br>**NOTE: with standard HW the capability to use encoders with high number of pulses could be limited depending on the speed. Ask to Zapi technicians before changing this parameter.** |
| **MOTOR P. PAIRS 1**<br><br>(T, TM, P, CO) | 1 ÷ 30 | This parameter defines the number of pole pairs of the traction motor. It must be set equal to MOTOR P. PAIRS 2; otherwise the controller raises an alarm. |
| **MOTOR P. PAIRS 2**<br><br>(T, TM, P, CO) | 1 ÷ 30 | This parameter defines the number of pole pairs of the traction motor. It must be set equal to MOTOR P. PAIRS 1; otherwise the controller raises an alarm. |

## 8.2.6  HYDRO SETTING

| HYDRO SETTING | | |
|---|---|---|
| **Parameter** | **Allowable range** | **Description** |
| **HYDRO TIME**<br><br>(A) | 0 s ÷ 20 s<br><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><br>(A) | NONE ÷ OPTION#2 | This parameter defines how the pump feeding hydraulics is managed.<br><br>**NONE =** hydraulic function is not present.<br><br>**KEYON =** ACE2 constantly drives the pump motor from key-on.<br><br>**RUNNING =** ACE2 drives the pump motor only upon an associated request.<br><br>**OPTION#1 =** like setting KEYON.<br><br>**OPTION#2 =** like setting RUNNING. |

## 8.3  TESTER function

The TESTER function gives real- time feedbacks about the state of the controller, the motor and command devices. It is possible to know the state (active/inactive, on/off) of the digital I/Os, the voltage value of the analog inputs and the state of the main variables used for the motor and hydraulics control.

In the following tables, "Parameter" columns also report between brackets lists of the controller types where each parameter is available.

Controller types are coded as:

**A =** All controller types
**T =** Traction controllers (in single motor applications)
**TM =** Traction main controllers (in multiple motor applications)
**TS =** Traction secondary controllers (in multiple motor applications)
**P =** AC pump controllers
**CO =** CANopen controllers
**N =** none

### 8.3.1  TESTER – Master microcontroller

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

| TESTER menu (Master) | | |
|---|---|---|
| **Parameter** | **Unit of measurement (resolution)** | **Description** |
| **KEY VOLTAGE** <br><br> (A) | Volt (0.1 V) | Key voltage measured in real time. |
| **BATTERY VOLTAGE** <br><br> (A) | Volt (0.1 V) | Battery voltage measured in real time (across the DC bus). |
| **DC BUS CURRENT** <br><br> (A) | Ampere (1 A) | Estimation of the DC current the inverter is drawing from the battery. |
| **BATTERY CHARGE** <br><br> (A) | Percentage (1%) | Estimation of the battery charge based on the battery voltage. |
| **MOTOR VOLTAGE** <br><br> (A) | Percentage (1%) | Theoretical phase- to- phase voltage to be applied at the motor terminals, as a percentage of the supply voltage. <br><br> The actual applied voltage is changed by INDEX OVERMOD. (see next item). |
| **INDEX OVERMOD.** <br><br> (A) | Percentage (1%) | Correction applied to the motor-voltage set-point in order to compensate for the actual battery voltage. <br><br> The actual motor voltage delivered is the product of MOTOR VOLTAGE and INDEX OVEMOD. |
| **FREQUENCY** <br><br> (A) | Hertz (0.1 Hz) | Frequency of the current sine-wave that the inverter is supplying to the motor. |

| TESTER menu (Master) | | |
|---|---|---|
| **Parameter** | **Unit of measurement (resolution)** | **Description** |
| **MEASURED SPEED** (A) | Hertz (0.1 Hz) | Motor speed measured through the encoder and expressed in the same unit of FREQUENCY (Hz). |
| **SLIP VALUE** (A) | Hertz (0.01 Hz) | Motor slip, i.e. difference between the current frequency and the motor speed (in Hz). |
| **CURRENT RMS** (A) | Ampere (1 A) | Root-mean-square value of the line current supplied to the motor. $$Current\ [Arms] = \sqrt{I_Q{}^2 + I_D{}^2}$$ |
| **IMAX LIM. TRA** (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 actual conditions (inverter temperature, motor temperature, etc.). |
| **IMAX LIM. BRK** (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 actual conditions (inverter temperature, motor temperature, etc.). |
| **ID FILTERED RMS** (A) | Ampere (1 A) | Projection of the current vector on the d-axis, expressed in root-mean-square Ampere. |
| **IQ FILTERED RMS** (A) | Ampere (1 A) | Projection of the current vector on the q-axis, expressed in root-mean-square Ampere. |
| **IQIMAX LIM. TRA** (A) | Ampere (1 A) | Maximum value of the q-axis current component, according to traction-related settings, expressed in root-mean-square Ampere |
| **IQIMAX LIM. BRK** (A) | Ampere (1 A) | Maximum value of the q-axis current component, according to braking-related settings, expressed in root-mean-square Ampere. |
| **FLAGS LIMITATION** (A) | ON, OFF | Flag for any current limitation being active, for example thermal current cutback, maximum current reached, etc. . |
| **MOT. POWER WATT** (A) | Watt (1 W) | Estimation of the power supplied to the motor. |
| **STATOR FLUX MWB** (A) | $10^{-3}$ Weber (0.1 mWb) | Estimation of the motor magnetic flux. |
| **MOTION TORQUE NM** (A) | Newton Meter (0.1 Nm) | Estimation of the motor torque. |
| **STEER ANGLE** (T, TM) | Degrees (1°) | Current steering- wheel angle. When the steering is straight ahead STEER ANGLE is zero. |

## TESTER menu (Master)

| Parameter | Unit of measurement (resolution) | Description |
|---|---|---|
| **TEMPERATURE** (A) | Celsius degrees (1 °C) | Temperature measured on the inverter base plate. This temperature is used for the HIGH TEMPERATURE alarm. |
| **MOTOR TEMPERAT.** (A) | Celsius degrees (1 °C) | Motor-windings temperature. Normally the sensor is a PTC Philips KTY84-130. This temperature is used for the MOTOR OVERTEMP alarm. |
| **A19 TILLER SW** (T, TM) | OFF/ON | Status of the TILLER/SEAT input A19. |
| **A6 QI/PB SW** (T, TM) | OFF/ON | Status of the Pedal-Brake/Quick-Inversion input A6. |
| **A4 FW SW** (T, TM) | OFF/ON | Status of the forward input A4. |
| **A4 FW-INCH** (TS) | OFF/ON | Status of the forward inch input A4. |
| **A4 ENABLE** (T, TM, TS) | OFF/ON | Status of the driving-demand input A4. |
| **A5 BW SW** (T, TM) | OFF/ON | Status of the backward input A5. |
| **A5 BW-INCH** (TS) | OFF/ON | Status of the backward inch input A5. |
| **A10 AUX1** (T, TM) | OFF/ON | Status of the AUX1 input A10. |
| **A3 SR/HB** (T, TM) | OFF/ON | Status of the Speed reduction / Handbrake input A3. |
| **A19 SEAT SW** (P) | OFF/ON | Status of the Seat Input on A19. |
| **A5 SPD1 SW** (P) | OFF/ON | Status of the 1ST-speed input A5. |
| **A4 LFT/E SW** (P) | OFF/ON | Status of the lift input A4. |
| **A10 LOWER SW** (P) | OFF/ON | Status of the lowering input A10. |

| TESTER menu (Master) | | |
|---|---|---|
| **Parameter** | **Unit of measurement (resolution)** | **Description** |
| **A6 SPD2 SW** (P) | OFF/ON | Status of the 2<sup>ND</sup>-speed input A6. |
| **A3 SPD3 SW** (P) | OFF/ON | Status of the 3RD-speed input A3. |
| **NODE ID** (CO) | 0 ÷ 56 | Node ID setting for CANopen Protocol |
| **TARGET SPEED** (CO) | daHz (10 Hertz) | Speed setpoint transmitted over CANopen protocol. It is expressed in tenths of Hz. |
| **BRAKING REQUEST** (CO) | 0 ÷ -255 | Braking setpoint transmitted over CANopen protocol. |
| **CONTROL WORD** (CO) | 0 ÷ -65535 | Control Word transmitted upon CANopen protocol. |
| **CONTROL WORD 2** (CO) | 0 ÷ -65535 | Control Word 2 transmitted upon CANopen protocol. |
| **STATUS WORD** (CO) | 0 ÷ -65535 | It shows the Status Word travelling upon CANopen protocol. |
| **WARNING SYSTEM** (CO) | 0 ÷ -65535 | In case of warning, it shows the related warning code. |
| **TORQUE REQ.** (CO) | Newton Meter (1 Nm) | Torque setpoint for AC motor in CANopen configuration. |
| **TORQUE BRK REQ.** (CO) | Newton Meter (1 Nm) | Torque setpoint during braking for AC motor in CANopen configuration. |
| **A13 POT#1** (A) | Volt (0.01V) | Voltage of the analog signal on A13. |
| **A6 POT#2** (A) | Volt (0.01V) | Voltage of the analog signal on A6 |
| **A3 POT#3** (A) | Volt (0.01V) | Voltage of the analog signal on A3 |
| **A10 POT#4** (A) | Volt (0.01V) | Voltage of the analog signal on A10 |

| TESTER menu (Master) | | |
|---|---|---|
| **Parameter** | **Unit of measurement (resolution)** | **Description** |
| **A-5 BLSIN POT#5**<br><br>(A – **Only for** BLE2 **with sin/cos sensor)** | Volt (0.01V) | Voltage of the analog signal on A5. |
| **SIN FB. INPUT**<br><br>(A – **Only for** BLE2 **with sin/cos sensor)** | Volt (0.01 V01V) | Voltage of sine input A13. |
| **COS FB. INPUT**<br><br>(A – **Only for** BLE2 **with sin/cos sensor)** | Volt (0.01 V01V) | Voltage of cosine input A6. |
| **A9 OUTPUT EV1**<br><br>(A) | Percentage% (1%) | Setpoint of electrovalve EV1. |
| **A-16 MAIN CONT.**<br><br>(A) | Percentage% (1%) | Voltage applied over the main contactor coil. It corresponds to the duty cycle value of PWM applied and it is expressed in percentage. |
| **A-18 ELEC.BRAKE**<br><br>(A) | Percentage% (1%) | Voltage applied over the electro mechanic brake coil. It corresponds to the duty cycle value of PWM applied and it is expressed in percentage. |
| **BYTE 4 PDO1TX**<br><br>(CO) | Units | Information related to PDO1TX Byte 4. Refer to CAN protocol. |
| **BYTE 5 PDO1TX**<br><br>(CO) | Units | Information related to PDO1TX Byte 5. Refer to CAN protocol. |
| **BYTE 6 PDO1TX**<br><br>(CO) | Units | Information related to PDO1TX Byte 6. Refer to CAN protocol. |
| **BYTE 7 PDO1TX**<br><br>(CO) | Units | Information related to PDO1TX Byte 7. Refer to CAN protocol. |
| **BYTE 2 PDO2TX**<br><br>(CO) | Units | Information related to PDO2TX Byte 2. Refer to CAN protocol. |
| **BYTE 5 PDO2TX**<br><br>(CO) | Units | Information related to PDO2TX Byte 5. Refer to CAN protocol. |
| **WORD 6 PDO2TX**<br><br>(CO) | Units | Information related to PDO2TX Word 6. Refer to CAN protocol. |
| **CTRAP HW**<br><br>(A) | Units (1) | This is a counter and it is showing the number of occurrences of hardware- overcurrent occurrences detection. |

| TESTER menu (Master) | | |
| --- | --- | --- |
| **Parameter** | **Unit of measurement (resolution)** | **Description** |
| **A.SENS.OFFSET SR**<br><br>(A – **Only for BLE2 with sin/cos sensor**)<br><br>(A) | Digital units | This parameter shows the voltage offset of the encoder sine signal, in digital units, acquired during the absolute sensor acquisition automatic procedure. |
| **A.SENS.OFFSET CR**<br><br>(A – **Only for BLE2 with sin/cos sensor**)<br><br>(A) | Digital units\ | This parameter shows the voltage offset of the encoder cosine signals, in digital units, acquired during the absolute sensor acquisition automatic procedure. |
| **ANGLE OFFSET**<br><br>(A – **Only for BLE2 with sin/cos sensor**)<br><br>(A) | Degrees | This is the angle offset present between the orientation of the rotor and the position sensor. |
| **ANGLE OFFSET ENC**<br><br>(A – **Only for BLE2 with encoder**)<br><br>(A) | Degrees | This is the angle offset present between the orientation of the rotor and the index signal (on an ABI encoder). |
| **ROTOR POSITION**<br><br>(A – **Only for BLE2**)<br><br>(A) | Degrees | Real-This is the real time absolute orientation of the rotor, expressed in degrees. |
| **TRUCK SPEED**<br>(T, TM, CO) | km/h (0.1 km/h) | Speed of the truck (it requires custom software embedding gear ratio and wheels radius). |
| **ODOMETER KM**<br>(T, TM, CO) | km (1km) | 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. |

## 8.3.1.1 TESTER – Supervisor microcontroller

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

| TESTER menu (Supervisor) | | |
|---|---|---|
| **Parameter** | **Unit of measure (resolution)** | **Description** |
| **MEASURED SPEED**<br>(A) | Hertz (0.1 Hz) | Motor speed measured through the encoder and expressed in the same unit of FREQUENCY (Hz). |
| **CNA4**<br>(A) | OFF/ON | Status of input A4. |
| **CNA5**<br>(A) | OFF/ON | Status of input A5. |
| **CNA6**<br>(A) | OFF/ON | Status of input A6. |
| **CNA13**<br>(A) | OFF/ON | Status of input A13. |
| **CNA19**<br>(A) | OFF/ON | Status of input A19. |
| **A13 POT#1**<br>(A) | Volt (0.01V)OFF/ON | Voltage of analog input A13. |
| **A6 POT#2**<br>(A) | OFF/ON | Voltage of analog input A6. |
| **A3 POT#3**<br>(A) | Volt (0.01V) | It shows the voltage of the analog input A3. |
| **A10 POT#4**<br>(A) | Volt (0.01V) | It shows the voltage of the analog input A10. |
| **A-5 BLSIN POT#5**<br>(A) | Volt (0.01V) | It shows the voltage of the analog input A5. |

## 8.4  Description of ALARMS menu

ALARMS logbook in the MAIN menu records the alarms occurred on the controller. It has a FIFO (First Input First Output) structure which means that the oldest alarm is lost when the database is full and a new alarm occurs. The logbook is composed of locations where is possible to stack different types of alarms with:

**1)**  The alarm code
**2)**  The number of times that each alarm occurs consecutively
**3)**  The Hour Meter value when the last event of every alarm occurred
**4)**  The inverter temperature at the first occurrence of every alarm.

This function permits a deeper diagnosis of problems as the recent history can be revised.

Refer to chapter 10  for more information about alarm codes.

*NOTE: if the same alarm is continuously happening, the controller does not use new memory of the logbook, but only updates the last memory cell increasing the related counter (point 2) of previous list). Nevertheless, the hour meter indicated in this memory refers to the first time the alarm occurred. In this way, comparing this hour meter with the controller hour meter, it is possible to determine:*
 *- when this alarm occurred the first time;*
 *- how many hours are elapsed from the first occurrence to now;*
 *-how many times it has occurred in this period.*

# 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 MI and MA indicate the points where the direction switches close, while 0 represents the mechanical zero of the lever, i.e. its rest position. Also, the relationship between motor voltage (Vmot) and potentiometer voltage (Vacc) is shown. Before calibration, Vmot percentage is mapped over the default 0 – 5 V range; instead, after the adjustment procedure it results mapped over the useful voltage ranges of the potentiometer, for both directions.
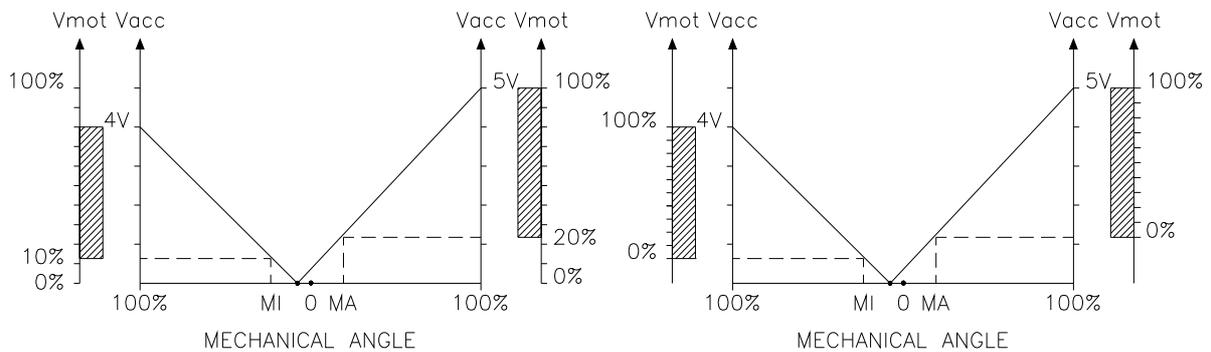


Before 'PROGRAM VACC'                    After 'PROGRAM VACC'

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 13.1.4 and 13.2.6.

## 9.2  PROGRAM LIFT / LOWER function

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

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

The values to be acquired are organized in the ADJUSTEMNT list, they are:
- MIN LIFT DC
- MAX LIFT DC
- MIN LOWER
- MAX LOWER

See paragraphs 13.1.5 or 13.2.7 for acquiring procedure.


## 9.3  PROGRAM STEER function

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

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

The values to be acquired are organized in the ADJUSTEMNT list, they are:
- STEER RIGHT VOLT
- STEER LEFT VOLT
- STEER ZERO VOLT

See paragraphs 13.1.6 or 13.2.8 for acquiring procedure.

## 9.4 Acceleration time

The ACCEL DELAY parameter allows to define the acceleration rate depending on the final-speed setpoint and on ACCEL MODULATION.

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

$$Accel\ time\ [s] = \frac{Speed\ setpoint\ [Hz]}{100\ Hz} \cdot Acceler\ delay\ [s]$$

- **ACCEL MODULATION = ON**
  Acceleration time is evaluated differently by software for setpoint values above or below 100 Hz.

  Case 1 (black trace in the graph):
  - Final-speed setpoint = 100 Hz
  - ACCEL DELAY = 2,5 s

Acceleration time results 2.5 s.

Case 2 (red trace in the graph):
  - Final-speed setpoint = 60 Hz
  - ACCEL DELAY = 2,5 s

Acceleration rate is re-scaled so that acceleration time results equal to ACCEL DELAY, in this case 2.5 s.

Case 3 (green trace in the graph):
  - Final-speed setpoint = 150 Hz
  - ACCEL DELAY = 2,5 s

Acceleration time results:

$$Accel\ time = \frac{150\ Hz}{100\ Hz} \cdot 2.5\ s = 3{,}75\ s$$
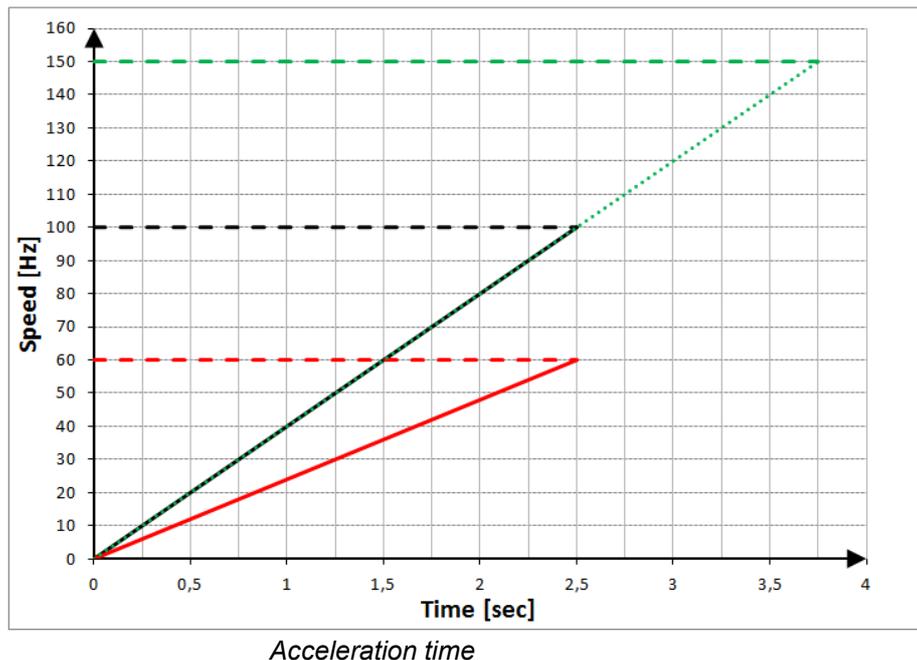


*Acceleration time*

## 9.5  Braking Delay

The DECEL. BRAKING parameter allows to define the deceleration rate depending on the final-speed setpoint. Deceleration time is evaluated differently by software for speed steps greater or smaller than 100 Hz.

Case 1 (black trace in the graph):
- Initial speed = 110 Hz
- Final-speed setpoint = 10 Hz
- DECEL. BRAKING = 2,5 s

The deceleration time results 2.5 s.

Case 2 (red trace in the graph):
- Initial speed = 60 Hz
- Final-speed setpoint = 10 Hz
- DECEL. BRAKING = 2,5 s

The deceleration rate is re-scaled so that the deceleration time results equal to DECEL. BRAKING, in this case 2.5 s.

Case 3 (green trace in the graph):
- Initial speed = 150 Hz
- Final-speed setpoint = 10 Hz
- DECEL. BRAKING = 2,5 s

The deceleration time results:

$$Decel\ time = \frac{150\ Hz}{100\ Hz} \cdot 2.5\ s = 3,75\ s$$



*Braking delay*
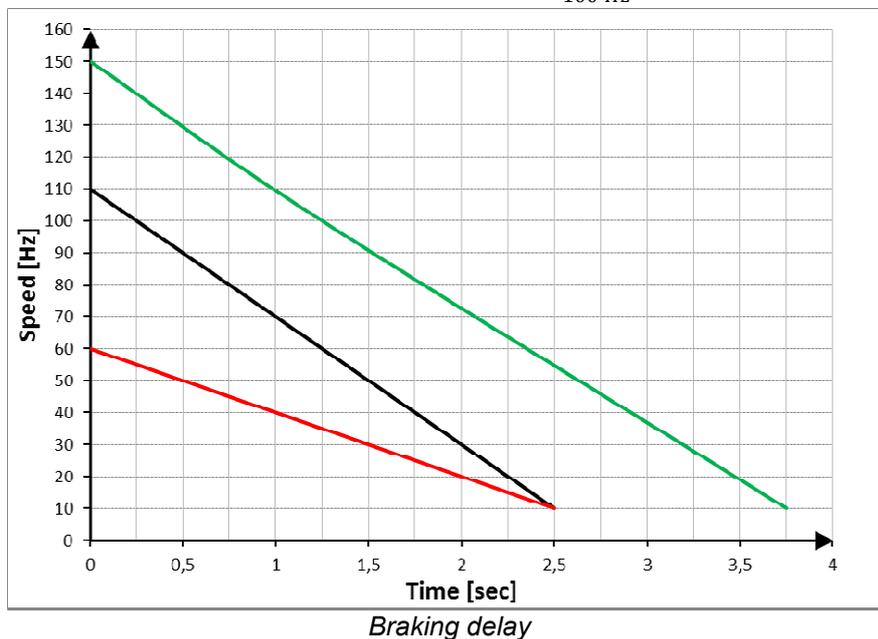
*Note: This example is valid for all the braking-related parameters: DECEL. BRAKING, INVER. BRAKING, RELEASE BRAKING, TILLER BRAKING, PEDAL BRAKING, SPEED LIMIT BRK, STEER BRAKING.*

## 9.6  Acceleration smoothness

Smoothing-related parameters define a parabolic profile for the acceleration or deceleration ramps close to 0 rpm. Values have not a phisycal meaning: 1 means linear ramp, higher values (up to 5) result in smoother accelerations.
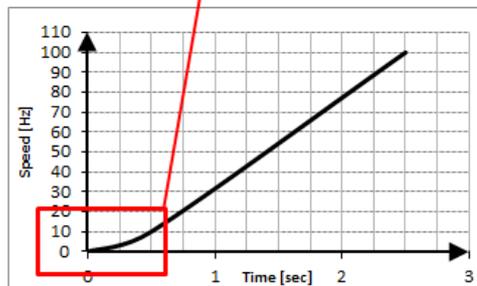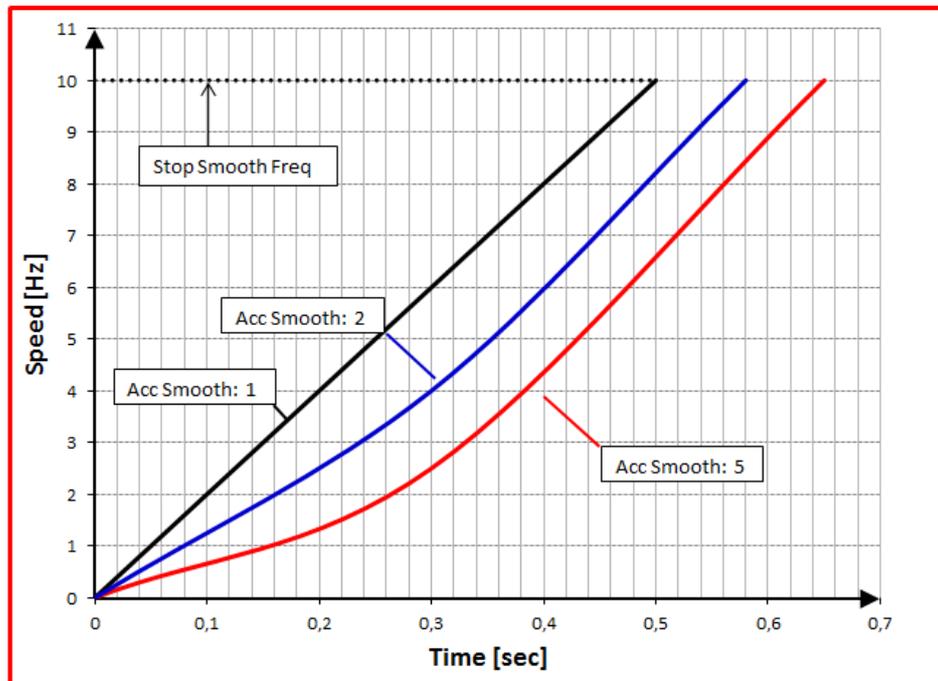


*Acceleration smoothness*

Note: This example is valid for ACC SMOOTH, BRK SMOOTH, INV SMOOTH.

## 9.7 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 CB 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*

---
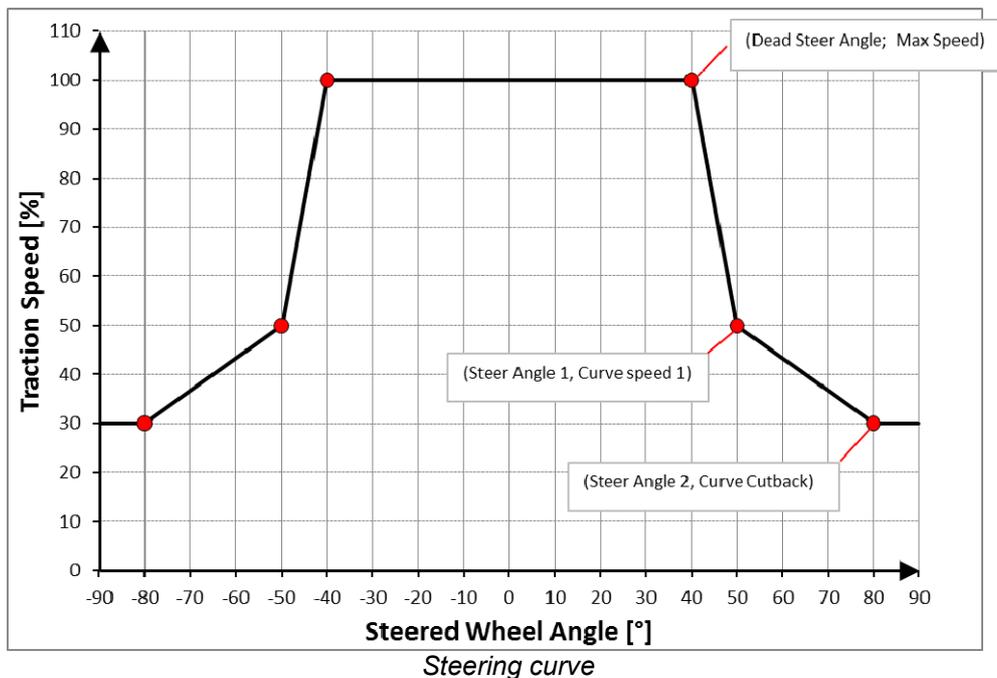
## 9.8 Throttle response

ACE2 controls the truck speed by means of a not linear function of the accelerator position, as to provide a better resolution of the speed control when the truck is moving slowly.

For the definition of such response, the following parameters are used:
- THROTTLE 0 ZONE [% of MAX VACC]
- THROTTLE X1 POINT [% of MAX VACC]
- THROTTLE Y1 POINT [% of MAX SPEED]
- THROTTLE X2 POINT [% of MAX VACC]
- THROTTLE Y2 POINT [% of MAX SPEED]
- THROTTLE X3 POINT [% of MAX VACC]
- THROTTLE Y3 POINT [% of MAX SPEED]

The speed remains at the FREQUENCY CREEP value as long as the voltage from the accelerator potentiometer is below THROTTLE 0 ZONE. Basically this defines a dead zone close to the neutral position.
For higher potentiometer voltages, the speed setpoint grows up as a polygonal chain defined by the following table of points.

| Throttle signal [% of MAX VACC] | Speed setpoint [% of MAX VACC] |
|---|---|
| 0 | FREQUENCY CREEP |
| THROTTLE 0 ZONE | FREQUENCY CREEP |
| THROTTLE X1 POINT | THROTTLE Y1 POINT |
| THROTTLE X2 POINT | THROTTLE Y2 POINT |
| THROTTLE X3 POINT | THROTTLE Y3 POINT |
| MAX VACC | MAX SPEED |

The following graph better displays the throttle – speed relationship.
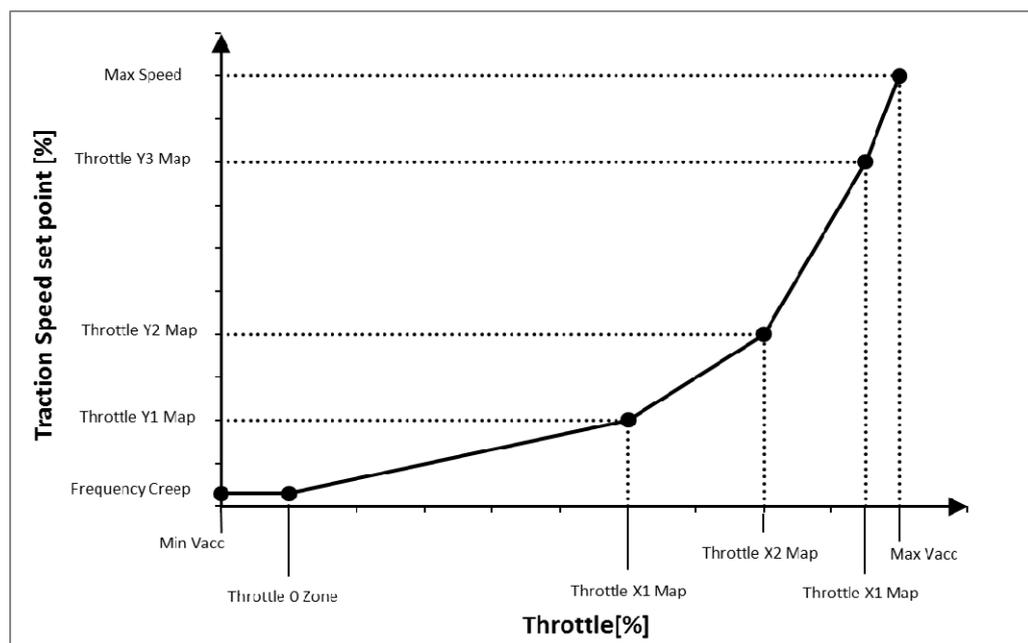
# 9.9NLC & NEB output

For the NLC output [or NEB output] there is the possibility to set a pull-in voltage and to define a retention voltage continuously applied to the coil.

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

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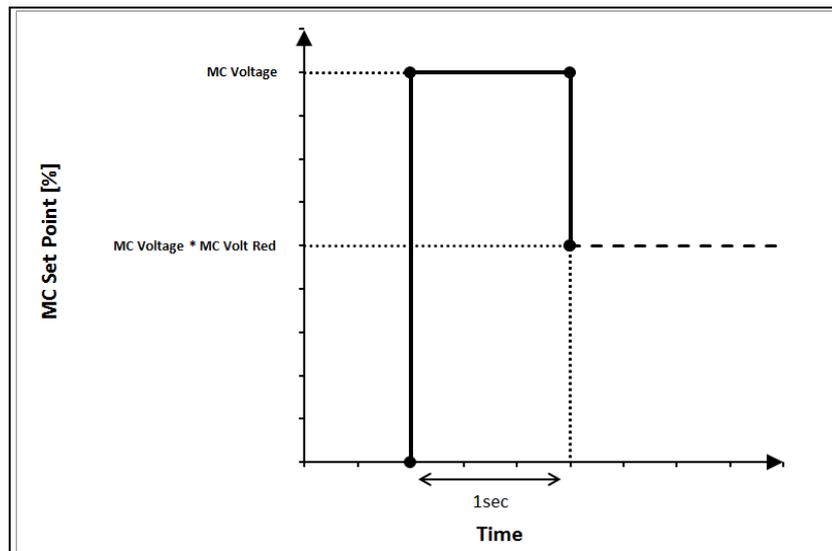


*NMC & NEB Output management*

Example 1:
MC VOLTAGE = 100%
MC VOLTAGE RED = 70%
Contactor is closed by applying 100% of duty-cycle to the coil and then then it is reduced to 70%.

Example 2:
MC VOLTAGE = 70%
MC VOLTAGE RED. = 100%
Contactor is closed by applying 70% of duty-cycle to the coil and then it is kept at the same value.

Example 3:
MC VOLTAGE = 70%
MC VOLTAGE RED = 70%
Contactor is closed by applying 70% of duty-cycle to the coil and then it is reduced to 49% (70% of 70%).

## 9.10 Battery-charge detection

During operating condition, the battery-charge detection makes use of two parameters that specify the full-charge voltage (100%) and the discharged-battery voltage (10%): BAT.MAX.ADJ and BAT.MIN.ADJ.

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

Moreover, BDI ADJ STARTUP adjusts the level of the battery charge table at the start-up, in order to evaluate the battery charge at key-on. The minimum variation of the battery charge that can be detected depends on the BDI RESET parameter.

The battery-charge detection works as the following procedure.

Start-up
   1) The battery voltage is read from 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, hereafter addressed as Vbatt.
   2) Vbatt is compared with a threshold value which comes as function of the actual charge percentage; by this comparison a new charge percentage is obtained.
   3) The threshold value can be changed with the BDI ADJ STARTUP parameter.
   4) If the new charge percentage is within the range "last percentage (last value stored in EEPROM) ± BDI RESET" it is discarded; otherwise charge percentage is updated with the new value.

Operating condition
Measure of the battery voltage, together with the charge percentage at the time of the voltage sampling, give information about the instantaneous battery current.

   1) The battery voltage is read when the battery current is not zero, which is when the output power stage is driven. Vbatt is evaluated as the average value over a window of time.
   2) Vbatt is compared with a threshold value which comes as function of the actual charge percentage; by this comparison the current provided by the battery is obtained.
   3) Current obtained at step 2 integrated over time returns the energy drawn from the battery, in Ah.
   4) Charge percentage is dynamically updated basing on the energy from step 3.

Threshold values for the battery charge can be modified by means of BAT.MAX.ADJ. and BAT.MIN.ADJ. as to adapt the battery-charge detection to the specific battery in use.

## 9.11 Torque profile

By setting the proper parameter, it is possible to define a limit for the maximum torque demand (through set points) in the weakening area, for matching two goals:
1. Not overtaking the maximum torque profile of the motor.
2. Superimposing a limiting profile to the maximum torque as to get different drive performances (Eco mode, Medium performance, High performance).)
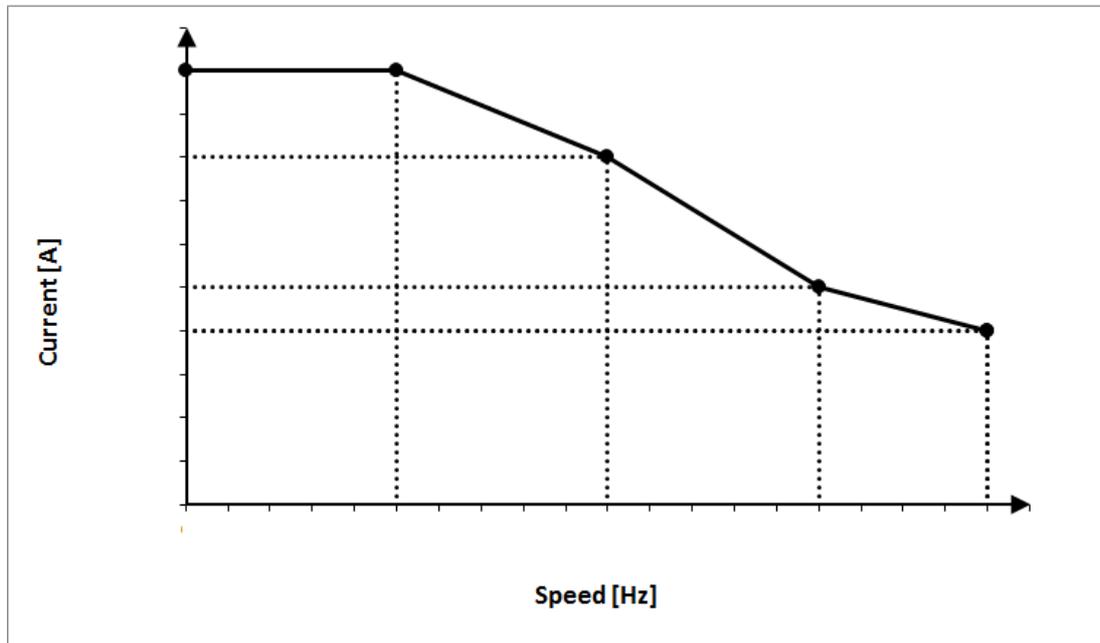


*Torque profile*
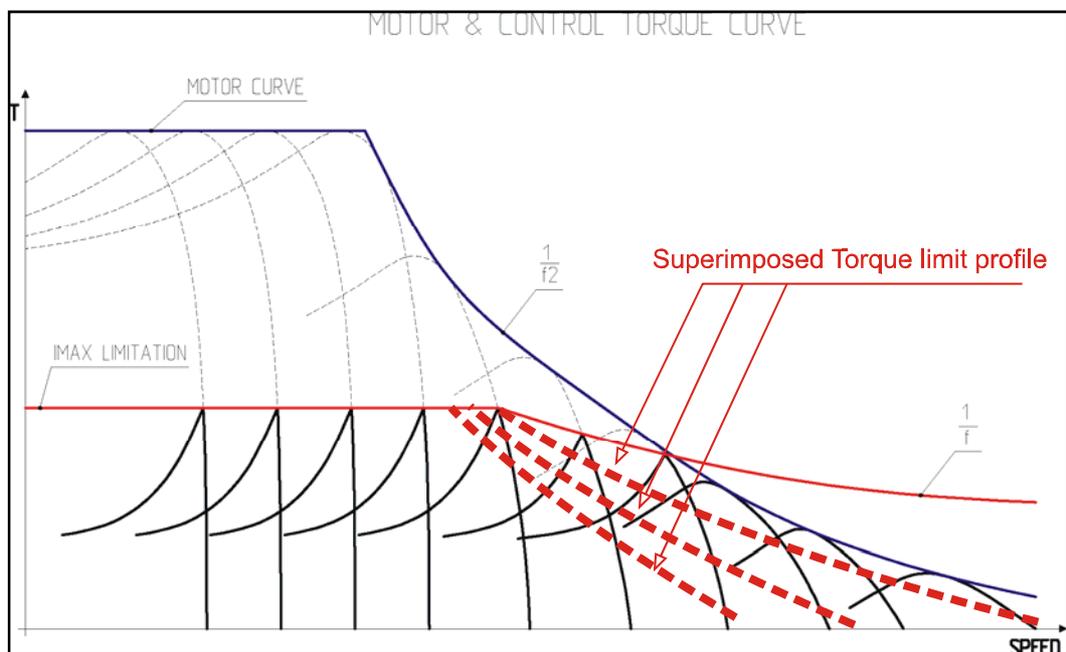


*Torque curves*

## 9.12 Steering table

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

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

- **NONE** = custom steering table, according to the following parameters:
  - o WHEELBASE MM: distance between the front axle and the rear axle of the truck.
  - o FIXED AXLE MM: axle width of the axle where the fixed wheels are.
  - o STEERING AXLE MM: axle width of the axle where the steering wheels are.
  
  All three previous parameters must be expressed in millimeters.

- **OPTION#1** = three-wheels predefined steering table.

- **OPTION#2** = four-wheels predefined steering table
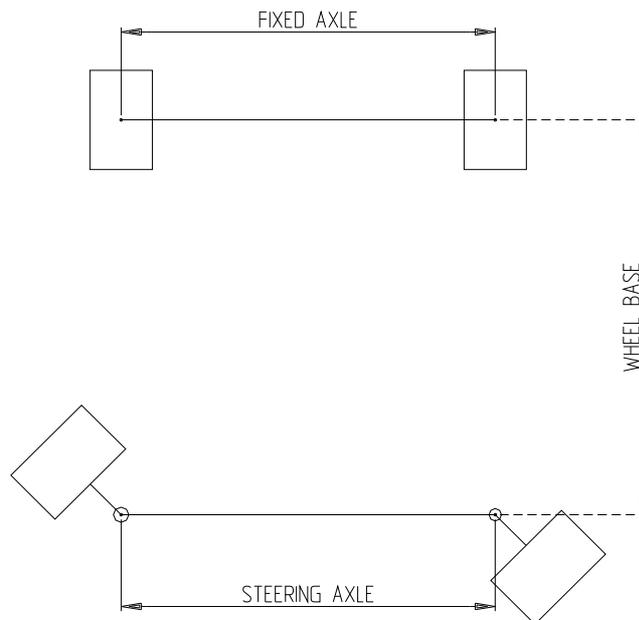


*Geometrical steering-related parameters.*

## 9.13 Motor thermal protection

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

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

A linear reduction is performed for temperatures between MAX. MOTOR TEMP. and STOP MOTOR TEMP. . It acts scaling down the torque profile (see paragraph 9.11) by a percentage from 100% to MOT.T. T.CUTBACK.

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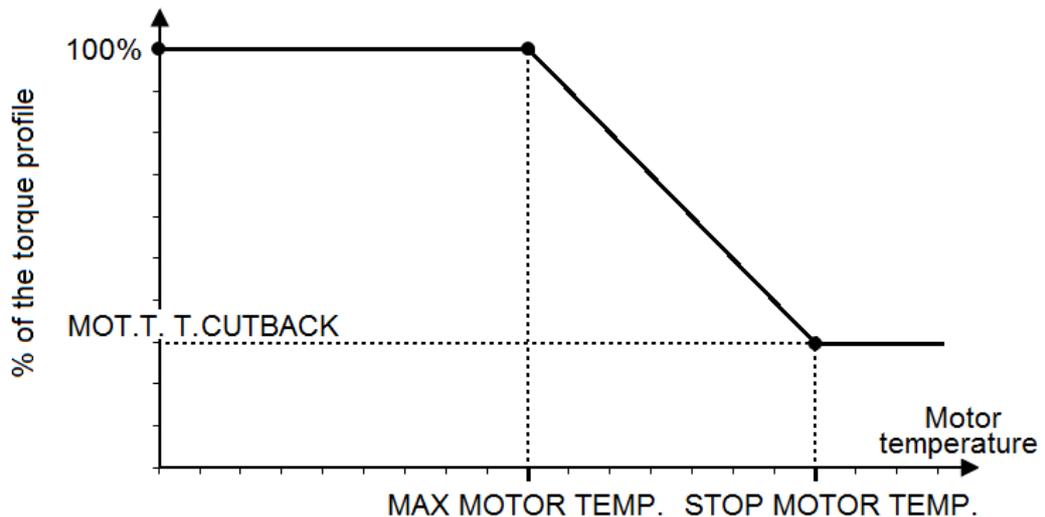


*Cutback is valid only during motoring, instead during braking the 100% of the maximum current is always available regardless the motor temperature.*

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

# 10 FAULTS DIAGNOSTIC SYSTEM

The diagnostic system of ACE2 provides the operator with information about a wide set of faults or problem that the controller can encounter.

– Faults which cause the power section to stop, meaning the power bridge opens and, when possible, the main contactor opens and the electromechanical brake is applied. They can be related to hardware failures that forbid to run the motor or safety-related failures.

– Problems which do not imply to stop the truck or allow to stop it by mean of a controlled regenerative braking. The controller still works, but it has detected conditions that require to stop the truck or at least to reduce its performance.

## 10.1 Alarms from master µC

| 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 stopped | Start-up, stand-by, running | Key re-cycle | 0 | 0000 | 224 |
| BATTERY LOW | According to parameter BATTERY CHECK (SET OPTIONS list, paragraph 8.2.2). | Start-up, standby, running | Battery recharge, key re-cycle | 0 | FF42 | 66 |
| DATA ACQUISITION | Traction is stopped | Controller calibration | Traction request | 0 | 0000 | 247 |
| CHECK UP NEEDED | | Start-up | Check-up done, key re-cycle | 0 | 0000 | 249 |
| RPM HIGH | MC is opened, Traction/Pump stopped | Start-up, standby, running | | 0 | FFA1 | 161 |
| BUMPER STOP | Traction is stopped | Start-up, standby, running | | 0 | FFA2 | 162 |
| WARNING SLAVE | It depends by the supervisor uC | | | 1 | FF01 | 244 |
| ACQUIRING A.S. | | Sensor Acquiring | Key re-cycle | 2 | FFAB | 171 |
| ACQUIRE END | | Sensor Acquiring | Key re-cycle | 2 | FFAD | 173 |
| ACQUIRE ABORT | | Sensor Acquiring | Key re-cycle | 2 | FFAC | 172 |
| SIN/COS D.ERR XX | MC is not closed, EB is applied, Traction/Pump, valves stopped | running | Key re-cycle | 3 | FFA8 | 168 |
| ENCODER D.ERR XX | Traction is stopped | running | Key re-cycle | 3 | FFA9 | 169 |
| HOME SENS.ERR XX | MC is opened , EB is applied, EVP stopped | Running | Key re-cycle | 3 | FFB0 | 176 |
| OFFSET SPD.SENS. | EB is applied, Traction/Pump, valves stopped. | Start-up | Perform ABS SENS. ACQUIRE | 3 | FF99 | 153 |
| PWM ACQ. ERROR | MC is not closed, EB is applied, Traction/Pump, valves stopped | Start-up | Key re-cycle | 6 | FFA4 | 164 |
| ED SLIP MISMATCH | MC is opened, EB is applied, Traction/Pump stopped | Running | Valves or Traction/Pump request | 7 | FFA3 | 163 |
| WATCHDOG | MC is opened, EB is applied, Traction/Pump, valves stopped | Start-up, stand-by, running | Key re-cycle | 8 | 6010 | 8 |

| Error code | Effect | Condition | Restart procedure | MDI / LED CODE | CAN OPEN CODE | ZAPI CODE |
|---|---|---|---|---|---|---|
| EVP DRIVER OPEN | MC is opened (the command is released), EB is applied, Traction/Pump, valves stopped | Start-up, stand-by, running | Valves request | 9 | FFF8 | 240 |
| EVP COIL OPEN | Valves stopped | Start-up, stand-by, running | Valves or Traction/Pump request | 9 | 5002 | 214 |
| EVP DRIV. SHORT. | MC is opened , EB is applied, EVP stopped | Start-up, stand-by, running | Traction/Pump request | 9 | 5003 | 215 |
| STALL ROTOR | Traction/Pump stopped | Start-up, stand-by, running | Valves or Traction/Pump request | 11 | FFD3 | 211 |
| CONTROLLER MISM. | MC is not closed, EB is applied, Traction/Pump, valves stopped | Start-up | Install the correct software and Key re-cycle | 12 | FFEF | 239 |
| EEPROM KO | Controller works using default parameters | Start-up, stand-by, running | | 13 | 3610 | 208 |
| PARAM RESTORE | No effect | Start-up | Traction/Pump request | 14 | 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. | MC is not closed, EB is applied, Traction/Pump stopped | Start-up | Key re-cycle | 16 | FFEE | 238 |
| LOGIC FAILURE #3 | MC is opened, EB is applied, Traction/Pump, valves stopped | Start-up, stand-by | Valves or Traction/Pump request | 17 | FF11 | 17 |
| LOGIC FAILURE #2 | MC is not closed, EB is applied, Traction/Pump, valves stopped | Start-up, stand-by, | Valves or Traction/Pump request | 18 | FF12 | 18 |
| LOGIC FAILURE #1 | MC is not closed, EB is applied, Traction/Pump, valves stopped | Stand-by, running | Valves or Traction/Pump request | 19 | 5114 | 19 |
| VKEY OFF SHORTED | MC is not closed, EB is applied, Traction/Pump stopped | Start-up | Key re-cycle | 20 | 5101 | 220 |
| CONT. DRV. EV | Valves stopped | Start-up, stand-by, running | Valves request | 21 | FFE8 | 232 |
| DRV. SHOR. EV | Valves stopped | Start-up, stand-by, running | Valves or Traction/Pump request | 21 | FFF9 | 234 |
| OPEN COIL EV. | MC remains closed, EB is applied, Traction/Pump, valves stopped (the command is released | Start-up, Stand-by, running | Valves or Traction/Pump Request | 21 | FFF2 | 242 |
| LC COIL OPEN | MC is not closed, EB is applied, Traction/Pump, valves stopped | Start-up, stand-by, running | Valves or Traction/Pump request | 22 | FFE6 | 230 |
| IQ MISMATCHED | Traction is stopped | Running | Valves or Traction/Pump request | 24 | FFF5 | 245 |
| PEV NOT OK | Pump motor stopped, valves stopped | Start-up, stand-by, running | Valves request | 25 | FFDB | 217 |
| INIT VMN LOW | MC is not closed, EB is applied, Traction/Pump, valves stopped | Start-up | Valves or Traction/Pump request | 30 | 3121 | 207 |
| VMN LOW | MC is not closed, EB is applied, Traction/Pump, valves stopped | Start-up | Valves or Traction/Pump request | 30 | 3120 | 30 |
| INIT VMN HIGH | MC is not closed, EB is applied, Traction/Pump, valves stopped | Start-up | Valves or Traction/Pump request | 31 | 3111 | 206 |
| VMN HIGH | MC is not closed, EB is applied, Traction/Pump, valves stopped | Start-up, stand-by | Valves or Traction/Pump request | 31 | 3110 | 31 |
| HW FAULT | MC is not closed, EB is applied, Traction/Pump stopped | Start-up | Key re-cycle | 32 | FFE3 | 227 |
| HW FAULT EB. | MC is opened, EB is applied, Traction/Pump stopped | Start-up | Key re-cycle | 34 | FFE5 | 229 |

| Error code | Effect | Condition | Restart procedure | MDI / LED CODE | CAN OPEN CODE | ZAPI CODE |
|---|---|---|---|---|---|---|
| POSITIVE LC OPEN | MC is not closed, EB is applied, Traction/Pump, valves stopped | Start-up, stand-by, running | Valves or Traction/Pump request | 35 | FFD5 | 213 |
| FIELD ORIENT. KO | MC is opened, EB is applied, Traction/Pump, valves stopped | Running | Valves or Traction/Pump request | 36 | FFFD | 253 |
| CONTACTOR CLOSED | MC is not closed (command is not activated), EB is applied, Traction/Pump stopped | Start-up | Valves or Traction/Pump request | 37 | 5442 | 37 |
| CONTACTOR OPEN | MC is opened, EB is applied, Traction/Pump, valves stopped | Start-up, stand-by, running | Valves or Traction/Pump request | 38 | 5441 | 38 |
| POWER MISMATCH | Traction is stopped, EB is applied, MC is opened | Running | Traction/Pump request | 39 | FFD4 | 212 |
| EB. DRIV.SHRT. | MC remains closed, EB is applied (the command is released), Traction/Pump, valves stopped | Stand-by, running | Valves or Traction/Pump Request | 40 | 3222 | 254 |
| WRONG SET BAT. | MC is not closed, EB is applied, Traction/Pump, valves stopped | Start-up | | 41 | 3100 | 251 |
| WRONG KEY VOLT. | MC is not closed, EB is applied, Traction/Pump, valves stopped | Start-up | | 41 | 3101 | 170 |
| EB. DRIV.OPEN | MC remains closed, EB is applied (the command is released), Traction/Pump, valves stopped | Running | Valves or Traction/Pump Request | 42 | 3224 | 246 |
| EB. COIL OPEN | MC remains closed, EB is applied (the command is released), Traction/Pump, valves stopped | Start-up, Stand-by, running | Valves or Traction/Pump Request | 43 | FFD8 | 216 |
| WAIT MOTOR STILL | MC is not closed, EB is applied, Traction/Pump stopped | Start-up | | 45 | FF9B | 155 |
| HANDBRAKE | Traction/Pump motor is stopped | Start-up, stand-by, running | Traction/Pump request | 46 | FFDD | 221 |
| MOT.PHASE SH. | MC is not closed, EB is applied, Traction/Pump, valves stopped | Start-up | Traction/Pump request | 47 | FFC4 | 196 |
| THROTTLE PROG. | MC remains closed, EB is applied (the command is released), Traction stopped | Start-up, Stand-by, running | Valves or Traction/Pump Request | 48 | FFF3 | 243 |
| LIFT + LOWER | Pump is stopped | Start-up, stand-by, running | Pump request | 49 | FFBB | 187 |
| TILLER OPEN | LC opens | Start-up, stand-by, running | Valves or Traction/Pump Request | 51 | 0000 | 228 |
| STBY I HIGH | MC is not closed, EB is applied, Traction/Pump stopped | Start-up, stand-by | Valves or Traction/Pump request | 53 | 2311 | 53 |
| OVERLOAD | MC is not closed, EB is applied, Traction/Pump stopped | Running | Valves or Traction/Pump request | 57 | FFB4 | 180 |
| WRONG ZERO | MC is opened, EB is applied, Traction/Pump, valves stopped | Start-up | Valves or Traction/Pump request | 58 | 3201 | 252 |
| CAPACITOR CHARGE | MC is not closed, EB is applied, Traction/Pump, valves stopped | Start-up | Valves or Traction/Pump request | 60 | 3130 | 60 |
| THERMIC SENS. KO | Maximum current is reduced according to parameter MOT.T. 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 stopped | Start-up, stand-by, running | or Traction/Pump Request | 63 | FFCC | 204 |
| MOTOR TEMPERAT. | Maximum current is linearly reduced (see paragraph 9.13) and speed is reduced to a fixed value. | Start-up, stand-by, running | | 65 | 4110 | 65 |

| Error code | Effect | Condition | Restart procedure | MDI / LED CODE | CAN OPEN CODE | ZAPI CODE |
|---|---|---|---|---|---|---|
| MOTOR TEMP. STOP | EB is applied, Traction/Pump, valves stopped | Start-up, stand-by, running | | 65 | FFB2 | 178 |
| NO CAN MSG. | MC is opened, EB is applied, Traction/Pump, valves stopped | Start-up, stand-by, running | Valves or Traction/Pump request | 67 | 8130 | 248 |
| SENS MOT TEMP KO | Maximum current is reduced according to parameter MOT.T. T.CUTBACK and speed is reduced to a fixed value. | Start-up, stand-by, running | | 68 | 4311 | 218 |
| EPS RELAY OPEN | Traction/Pump motor is stopped | Start-up, stand-by, Running | Valves or Traction/Pump request | 70 | FFCD | 205 |
| WRONG RAM MEM. | MC is opened, EB is applied, Traction/Pump, valves stopped | Stand-by | Key re-cycle | 71 | FFD2 | 210 |
| DRIVER SHORTED | MC is opened (the command is released), EB is applied, Traction/Pump, valves stopped | Start-up, stand-by, running | Valves or Traction/Pump request | 74 | 3211 | 74 |
| CONTACTOR DRIVER | MC is opened (the command is released), EB is applied, Traction/Pump, valves stopped | Start-up, stand-by, running | Valves or Traction/Pump request | 75 | 3221 | 75 |
| COIL SHOR. MC | MC is opened, EB is applied, Traction/Pump, valves stopped | Start-up (immediately after MC closing), stand-by, running | Valves or Traction/Pump request | 76 | 2250 | 223 |
| COIL SHOR. EB. | MC is opened, EB is applied, Traction/Pump, valves stopped | Start-up (immediately after MC closing), stand-by, running | Valves or Traction/Pump request | 76 | FFB1 | 177 |
| VDC LINK OVERV. | MC is not closed, EB is applied, Traction/Pump, valves stopped | Stand-by, running | Valves or Traction/Pump request | 77 | FFCA | 202 |
| VACC NOT OK | Traction/Pump motor is stopped | Start-up, stand-by, running | Traction/ request | 78 | FF4E | 78 |
| INCORRECT START | Traction/Pump motor is stopped | Start-up, stand-by | Traction request | 79 | FF4F | 79 |
| PUMP INC START | Pump motor is stopped | Start-up, stand-by, running | Pump request | 79 | FFBD | 189 |
| FORW + BACK | Traction is stopped | Start-up, stand-by, running | Traction request | 80 | FF50 | 80 |
| SPEED FB. ERROR | MC is opened , EB is applied, EVP stopped | Running | Valves or Traction/Pump request | 81 | FFAF | 175 |
| ENCODER ERROR | MC is opened, EB is applied, Traction/Pump, valves stopped | Running | Valves or Traction/Pump request | 82 | FF52 | 82 |
| WRONG ENC SET | MC is not closed, EB is applied, Traction/Pump, valves stopped | Start-up | Key re-cycle | 83 | FF51 | 181 |
| VACC OUT RANGE | Traction/Pump motor is stopped | Start-up, Stand-by, Running | Traction/Pump request | 85 | FFE2 | 226 |
| POWERMOS SHORTED | MC is opened, EB is applied, traction/pump stopped | Start-up | Key re-cycle | 89 | FFE9 | 233 |
| WRONG SLAVE VER. | MC opened, EB is applied, Traction/Pump, valves stopped | Start-up | Key re-cycle | 91 | FFC5 | 197 |
| CURRENT GAIN | Controller works, but with low maximum current | Start-up, stand-by | | 92 | 6302 | 236 |
| PARAM TRANSFER | MC stays closed, EB is applied, Traction/Pump, valves stopped | Start-up, stand-by, running | Key re-cycle | 93 | FFC7 | 199 |
| STEER SENSOR KO | Speed is reduced according to parameter CTB. STEER ALARM (PARAMETER CHANGE list, paragraph 8.2.1) | Start-up, stand-by, running | Return into correct range | 95 | FFB3 | 179 |
| ANALOG INPUT | MC is opened, EB is applied, traction/pump stopped | Stand-by, running | Key re-cycle | 96 | FFFA | 237 |
| M/S PAR CHK MISM | MC stays closed, EB is applied, Traction/Pump, valves stopped | Start-up | Save again the parameter and Key re-cycle | 97 | FFC6 | 198 |

| Error code | Effect | Condition | Restart procedure | MDI / LED CODE | CAN OPEN CODE | ZAPI CODE |
|---|---|---|---|---|---|---|
| TORQUE PROFILE | EB is applied, Traction/Pump motor is stopped | Start-up, stand-by | Valves or Traction/Pump request | 98 | FFC9 | 201 |

## 10.1.1 Troubleshooting of alarms from master µC

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

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

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

Troubleshooting:
The alarm ends when the acquisition is done.

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

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

**BATTERY LOW** *(MDI/LED code = 0)*
Cause:
Parameter BATTERY CHECK is other than 0 (SET OPTION list, paragraph8.2.2) and battery charge is evaluated to be lower than BATT.LOW TRESHLD (ADJUSTMENTS list, paragraph 8.2.3).

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

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

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

**BUMPER STOP** *(MDI/LED code = 0)*
Cause
The two digital inputs dedicated to the bumper functionality are high at the same time. The alarm can occur only if parameter BUMPER STOP = ON and only if ACE2 is in CAN OPEN configuration (see parameter CONTROLLER TYPE in SPECIAL ADJUST. list, paragraph 8.2.4).

Troubleshooting
- Turn off one or both inputs dedicated to the bumper functionality.
- If the alarm occurs even if the inputs are in the rest position, check if the microswitches are stuck.
- In case the problem is not solved, replace the logic board.

**CAPACITOR CHARGE** *(MDI/LED code = 60)*
It is related to the capacitor-charging system:
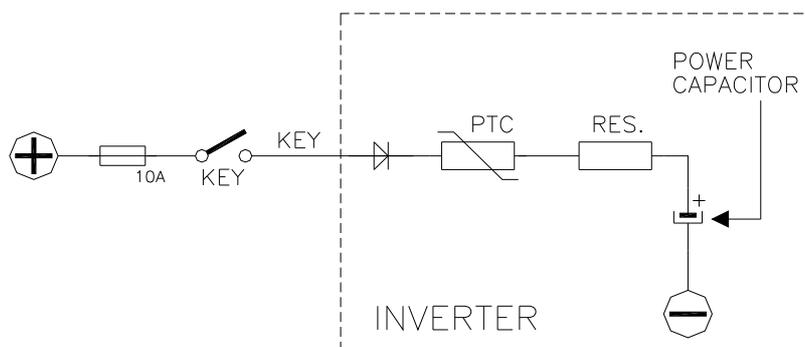


Cause
When the key is switched on, the inverter tries to charge the power capacitors through the series of a PTC and a power resistance, checking if the capacitors are charged within a certain timeout. If the capacitor voltage results less than a certain percentage of the nominal battery voltage, the alarm is raised and the main contactor is not closed.

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

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

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

**COIL SHOR. EB** *(MDI/LED code = 76)*
Cause
This alarm occurs when an overload of the EB driver (output NEB A18) occurs.

Troubleshooting
- Check the connections between the controller outputs and the loads.
- Collect information about characteristics of the coil connected to the driver and ask for assistance to a Zapi technician in order to verify that the maximum current that can be supplied by the hardware is not exceeded.
- In case no failures/problems have been found, the problem is in the controller, which has to be replaced.

**COIL SHOR. MC** *(MDI/LED code = 76)*
Cause
This alarm occurs when an overload of the MC driver (output NMC A16) occurs.

Troubleshooting
- Check the connections between the controller outputs and the loads.
- Collect information about characteristics of the coil connected to the driver and ask for assistance to a Zapi technician in order to verify that the maximum current that can be supplied by the hardware is not exceeded.
- In case no failures/problems have been found, the problem is in the controller, which has to be replaced.

**CONT. DRV. EV 02** *(MDI/LED code = 21)*
Cause:
AUX valve driver is not able to drive the load.

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

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

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

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

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

**CONTACTOR OPEN** *(MDI/LED code = 38)*

Cause

The LC coil is driven by the controller, but it seems that the power contacts do not close. In order to detect this condition the controller injects a DC current into the motor and checks the voltage on power capacitor. If the power capacitors get discharged it means that the main contactor is open.

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

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

Cause

The software is not compatible with the hardware. Each controller produced is "signed" at the end of line test with a specific code mark saved in EEPROM according to the customized Part Number.
According with this "sign", only the customized firmware can be uploaded.

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

**CURRENT GAIN** *(MDI/LED code = 92)*

Cause:

The maximum current gain parameters are at the default values, which means that the maximum current adjustment procedure has not been carried out yet.

Troubleshooting:

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

**DATA ACQUISITION** *(MDI/LED code = 0)*

Cause:

Controller in calibration state.

Troubleshooting:

The alarm ends when the acquisition is done.

**DRIVER SHORTED** *(MDI/LED code = 74)*

Cause

The driver of the LC coil is shorted.

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

**DRV. SHOR. EV 02** *(MDI/LED code = 21)*

Cause:

AUX valve driver is shorted.

Troubleshooting:
- Check if there is a short circuit or a low impedance path between the negative terminal of the coils and -B.

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

### EB. COIL OPEN *(MDI/LED code = 43)*
Cause:
This fault appears when no load is connected between the NEB output (A18) and the EB positive terminal PCOM (A17).

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

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

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

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

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

### ED SPLIP MISMATCH *(MDI/LED code = 7)*
Cause
The control detects a mismatch between the expected slip and the evaluated one. This diagnostic occurs only if ED COMPENSATION = TRUE.

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

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

**ENCODER D.ERR XX** *(MDI/LED code = 3)*

Cause:

This alarm occurs only when the controller is configured as PMSM and the feedback sensor selected is the encoder. The A and B pulse sequence is not correct. The hexadecimal value "XX" facilitates Zapi technicians debugging the problem.

Troubleshooting:
- Check the wirings.
- If the motor direction is correct, swap A and B signals.
- If the motor direction is not correct, swap two of the motor cables.
- If the problem is not solved, contact a Zapi technician.

**ENCODER ERROR** *(MDI/LED code = 82)*

Cause

This fault occurs when the frequency supplied to the motor is higher than 30 Hz and the signal feedback from the encoder has a too high jump in few tens of milliseconds. This condition is related to an encoder failure.

Troubleshooting
- Check the electrical and the mechanical functionality of the encoder and the wires crimping.
- Check the mechanical installation of the encoder, if the encoder slips inside its housing it will raise this alarm.
- Also the electromagnetic noise on the sensor can be the cause for the alarm. In these cases try to replace the encoder.
- If the problem is still present after replacing the encoder, the failure is in the controller.

**EPS RELAY OPEN** *(MDI/LED code = 70)*

Cause:

The controller receives from EPS information about the safety contacts being open.

Troubleshooting:

Verify the EPS functionality.

**EVP COIL OPEN** *(MDI/LED code = 9)*

Cause:

No load is connected between the NEVP output (A19) and the electrovalve positive terminal.

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

**EVP DRIV. SHORT.** *(MDI/LED code = 9)*

Cause
- The EVP driver (output A19) is shorted.
- The microcontroller detects a mismatch between the valve set-point and the feedback of the EVP output.

Troubleshooting
- Check if there is a short circuit or a low-impedance conduction path

between the negative of the coil and -B.
- Collect information about:
    o the voltage applied across the EVP coil,
    o the current in the coil,
    o features of the coil.
  Ask for assistance to Zapi in order to verify that the software diagnoses are in accordance with the type of coil employed.
- If the problem is not solved, it could be necessary to replace the controller.

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

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

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

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

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

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

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

Troubleshooting:
- Check that handbrake is not active by mistake.
- Check the SR/HB input state through the TESTER function.
- Check the wirings.
- Check if there are failures in the microswitches.
- If the problem is not solved, replace the logic board.

### HOME SENS.ERR XX *(MDI/LED code = 3)*
Cause
The controller detected a difference between the estimated absolute orientation of the rotor and the position of the index signal (ABI encoder).

It is caused by a wrong acquisition of the angle offset between the orientation of the rotor and the index signal. The hexadecimal value "XX" facilitates Zapi technicians debugging the problem.

Troubleshooting
Repeat the auto-teaching procedure.

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

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

### HW FAULT EV. 02 *(MDI/LED code = 16)*
Cause:
At start-up, the hardware circuit dedicated to enable and disable the EV driver (output NAUX1 A9) is found to be faulty.

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

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

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

### INCORRECT START *(MDI/LED code = 79)*
Cause:
Incorrect starting sequence. Possible reasons for this alarm are:
-    A travel demand active at key-on.
-    Man-presence sensor active at key on.

Troubleshooting:
-    Check wirings.
-    Check microswitches for failures.
-    Through the TESTER function, check the states of the inputs are coherent with microswitches states.
-    If the problem is not solved, replace the logic board.

### INIT VMN HIGH XX *(MDI/LED code = 31)*
Cause
Before closing the LC, the software checks the power-bridge voltage without driving it. The software expects the voltage to be in a "steady state" value.
If it is too high, this alarm occurs. 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.
- 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.

### INIT VMN LOW XX *(MDI/LED code = 30)*
Cause
Before closing the LC, the software checks the power-bridge voltage without driving it. The software expects the voltage to be in a "steady state" value. If it is too low, this alarm occurs. The hexadecimal value "XX" identifies the faulty phase:
- 01: phase U
- 02: phase V
- 03: phase W

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

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

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

### LC COIL OPEN *(MDI/LED code = 22)*
Cause
This fault appears when no load is connected between the NLC output A16 and the positive voltage (for example +KEY).

Troubleshooting
- Check the wiring, in order to verify if LC coil is connected to the right connector pin and if it is not interrupted.
- If the alarm is still present, than the problem is inside the logic board; replace it.

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

Troubleshooting:
- Check that LIFT and LOWER requests are not active at the same time.
- Check the LIFT and LOWER input states through the TESTER function.
- Check the wirings.

- Check if there are failures in the microswitches.
- If the problem is not solved, replace the logic board.

## LOGIC FAILURE #1 *(MDI/LED code = 19)*
Cause
This fault is displayed when the controller detects an undervoltage condition at the KEY input (A1). Undervoltage threshold depends on the nominal voltage of the controller.

| Nominal voltage | 24V | 36/48V | 72/80V | 96V |
|---|---|---|---|---|
| Undervoltage threshold | 10V | 10V | 30V | 30V |

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

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

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

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

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

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

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

Troubleshooting:
Restore and save again the parameters list.

**MOT.PHASE SH. XX** *(MDI/LED code = 47)*
Cause
Short circuit between two motor phases. The hexadecimal value "XX" identifies the shorted phases:
36: U – V short circuit
37: U – W short circuit
38: V – W short circuit

Troubleshooting
- Verify the motor phases connection on the motor side.
- Verify the motor phases connection on the inverter side.
- Check the motor power cables.
- Replace the controller.
- If the alarm does not disappear, the problem is in the motor. Replace it.

**MOTOR TEMP. STOP** *(MDI/LED code = 65)*
Cause:
The temperature sensor has overtaken the threshold defined by STOP MOTOR TEMP. (if analog, see paragraph 8.2.3).

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

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

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

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

Troubleshooting
- Verify the CANbus network (external issue).
- Replace the logic board (internal issue).

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

Troubleshooting:
Perform the teaching procedure: in OPTIONS, select ABS SENS. ACQUIRE. See paragraph 7.3.1 for more details.

## OPEN COIL EV. *(MDI/LED code = 21)*
Cause:
This fault appears when no load is connected between the NAUX1 output (A9) and the positive terminal PCOM (A17).

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

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

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

## PARAM RESTORE *(MDI/LED code = 14)*
Cause:
The controller has restored the default settings. If a CLEAR EEPROM 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 does cancel the alarm.
- If the alarm appears at key-on without any CLEAR EEPROM performed, replace the controller.

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

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

## PEV NOT OK *(MDI/LED code = 25)*
Cause:
Terminal PCOM is not connected to the battery or the voltage is different from that defined by parameter SET POSITIVE PEB (see the ADJUSTMENTS list, paragraph 8.2.3).
This alarm can occur if output NAUX1 is present (and the related setting is active) or the AUX OUT function is active.

Troubleshooting:
- Check PCOM terminal: it must be connected to the battery voltage (after the main contactor).
- Set the nominal PCOM voltage in parameter SET POSITIVE PEB in ADJUSTMENTS list (see paragraph 8.2.3).

**POSITIVE LC OPEN** *(MDI/LED code = 35)*
   Cause
   The positive voltage of LC is different from expected.

   Troubleshooting
   - Verify LC coil is properly connected.
   - Verify CONF. POSITIVE LC parameter is set in accordance with the actual coil positive supply (see paragraph 8.2.5). Software, depending on the parameter value, makes a proper diagnosis; a mismatch between the hardware and the parameter configuration could generate a false fault.
   - In case no failures/problems have been found, the problem is in the controller, which has to be replaced.

**POWER MISMATCH** *(MDI/LED code = 39)*
   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** *(MDI/LED code = 89)*
   Cause
   The DC-link voltage drops to zero when a high-side or low-side MOSFET is turned on.

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

**PWM ACQ. ERROR** *(MDI/LED code = 6)*
   Cause
   This alarm occurs only when the controller is configured to drive a PMSM and the feedback sensor selected in the HARDWARE SETTINGS list is ENCODER ABI + PWM.
   The controller does not detect correct information on PWM input at start-up.

   Troubleshooting
   - Re-cycle the key.
   - Check the sensor in order to verify that it works properly.
   - Check the wiring.
   - If the problem occurs permanently it is necessary to substitute logic board.

**PUMP INC START** *(MDI/LED code = 79)*
   Cause:
   Man-presence switch is not enabled at pump request.

   Troubleshooting:
   - Check wirings.
   - Check microswitches for failures.
   - Through the TESTER function, check the states of the inputs are coherent with microswitches states.
   - If the problem is not solved, replace the logic board.

**RPM HIGH** *(MDI/LED code = 0)*
Cause:
 This alarm occurs in Gen. Set versions when the speed exceeds the  threshold speed.

**SEAT MISMATCH** *(MDI/LED code = 15)*
Cause
This alarm can appear only in a Traction + Pump configuration or in a multi-motor one.
There is an input mismatch between the traction controller and the pump controller relatively to the TILLER/SEAT input (A6): the two values recorded by the two controllers are different.

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

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

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

**SIN/COS D.ERR XX** *(MDI/LED code = 3)*
Cause:
This alarm occurs only when the controller is configured as PMSM and the feedback sensor selected is sin/cos. The signal coming from sin/cos sensor has a wrong direction. The hexadecimal value "XX" facilitates Zapi technicians debugging the problem.

Troubleshooting:
- Check the wirings.
- If the motor direction is correct, swap the sin and cos signals.
- If the motor direction is not correct, swap two of the motor cables.
- If the problem is not solved, contact a Zapi technician.

**SPEED FB. ERROR** *(MDI/LED code = 81)*
Cause
This alarm occurs if the absolute position sensor is used also for speed estimation. If signaled, it means that the controller measured that the engine was moving too quick.

Troubleshooting
- Check that the sensor used is compatible with the software release.
- Check the sensor mechanical installation and if it works properly.
- Also the electromagnetic noise on the sensor can be a cause for the alarm.
- If no problem is found on the motor or on the speed sensor, the problem is inside the controller, it is necessary to replace the logic board.

**STALL ROTOR** *(MDI/LED code = 11)*
> Cause:
> The traction rotor is stuck or the encoder signal is not correctly received by the controller.

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

**STBY I HIGH** *(MDI/LED code = 53)*
> Cause
> In standby, the sensor detects a current value different from zero.
> Troubleshooting
> The current sensor or the current feedback circuit is damaged. Replace the controller.

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

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

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

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

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

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

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

Troubleshooting:
Set properly the throttle-related parameters (see paragraph 9.8).

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

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

### TORQUE PROFILE *(MDI/LED code = 98)*
Cause:
There is an error in the choice of the torque profile parameters.

Troubleshooting:
Check in the HARDWARE SETTINGS list the value of those parameters.

### VACC NOT OK *(MDI/LED code = 78)*
Cause:
At key-on and immediately after that, the travel demands have been turned off. This alarm occurs if the ACCELERATOR reading (in TESTER function) 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 *(MDI/LED code = 85)*
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).
- 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.** *(MDI/LED code = 77)*
Cause
This fault is displayed when the controller detects an overvoltage condition.
Overvoltage threshold depends on the nominal voltage of the controller.

| Nominal voltage | 24V | 36/48V | 72/80V | 96V |
|---|---|---|---|---|
| Overvoltage threshold | 35V | 65V | 115V | 130V |

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

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

**VKEY OFF SHORTED** *(MDI/LED code = 20)*
Cause
At key-on, the logic board measures a voltage value of the KEY input that is constantly out of range, above the maximum allowed value.

Troubleshooting
- Check that the battery has the same nominal voltage of the inverter.
- Check the battery voltage, if it is out of range replace the battery.
- In case the problem is not solved, replace the logic board.

**VMN HIGH** *(MDI/LED code = 31)*
Cause 1
Before switching the LC on, the software checks the power bridge: it turns on alternatively the low-side power MOSFETs and expects the phase voltages decrease down to -B. If the phase voltages are higher than a certain percentage of the nominal battery voltage, this alarm occurs.
Cause 2
This alarm may also occur when the start-up diagnosis has succeeded and so the LC has been closed. In this condition, the phase voltages are expected to be lower than half the battery voltage. If one of them is higher than that value, this alarm occurs.

Troubleshooting
- If the problem occurs at start-up (the LC does not close), check:
  - motor internal connections (ohmic continuity);
  - motor power cables connections;
  - if the motor connections are OK, the problem is inside the controller. Replace it.
- If the alarm occurs while the motor is running, check:
  - motor connections;
  - that the LC power contact closes properly, with a good contact;
  - if no problem is found, the problem is inside the controller. Replace it.

**VMN LOW** *(MDI/LED code = 30)*
Cause 1
Start-up test. Before switching the LC on, the software checks the power bridge:

it turns on alternatively the high-side power MOSFETs and expects the phase voltages increase toward the positive rail value. If one phase voltage is lower than a certain percentage of the rail voltage, this alarm occurs.

Cause 2
Motor running test. When the motor is running, the power bridge is on and the motor voltage feedback tested; if it is lower than expected value (a range of values is considered), the controller enters in fault state.

Troubleshooting
- If the problem occurs at start up (the LC does not close at all), check:
    - motor internal connections (ohmic continuity);
    - motor power-cables connections;
    - if the motor connections are OK, the problem is inside the controller; replace it.
- If the alarm occurs while the motor is running, check:
    - motor connections;
    - that the LC power contact closes properly, with a good contact;
    - if no problem is found, the problem is inside the controller. Replace it.

### WAIT MOTOR STILL *(MDI/LED code = 45)*
Cause:
The controller is waiting for the motor to stop rotating. This warning can only appear in ACE2 for brushless motors.

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

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

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

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

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

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

### WRONG ENC SET *(MDI/LED code = 83)*
Cause
Mismatch between "ENCODER PULSES 1" parameter and "ENCODER PULSES 2" parameter (see paragraph 8.2.5).

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

**WRONG KEY VOLT.** *(MDI/LED code = 41)*
Cause
The measured key voltage is not the right one for the inverter.

Troubleshooting
- Check if the SET KEY VOLTAGE parameter in the ADJUSTMENTS list is set in accordance with the key voltage.
- Check if the key voltage is ok using a voltmeter, if not check the wiring.
- In case the problem is not solved, replace the logic board.

**WRONG RAM MEM.** *(MDI/LED code = 71)*
Cause
The algorithm implemented to check the main RAM registers finds wrong contents: the register is "dirty". 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.** *(MDI/LED code = 41)*
Cause
At start-up, the controller checks the battery voltage (measured at key input) and it verifies that it is within a range of ±20% around the nominal value.

Troubleshooting
- Check that the SET BATTERY parameter inside the ADJUSTMENTS list matches with the battery nominal voltage.
- If the battery nominal voltage is not available for the SET BATTERY parameter inside the ADJUSTMENTS list, record the value stored as HARDWARE BATTERY RANGE parameter 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 key voltage measured with a voltmeter on pin A1. If it does not match, then modify the ADJUST BATTERY parameter according to the value read by the voltmeter.
- Replace the battery.

**WRONG ZERO** *(MDI/LED code = 58)*
Cause:
At start-up, the amplifiers used to measure the motor voltage sense voltages outside a fixed range.

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

## 10.2  Alarms from supervisor μC

| Error Code | Effect | Condition | Restart procedure | MDI / LED CODE | CAN OPEN CODE | ZAPI CODE |
|---|---|---|---|---|---|---|
| BUMPER STOP | Traction sopped | Start-up, stand-by, running | | 0 | FFC7 | 199 |
| WATCHDOG | MC is opened, EB is applied, traction/pump stopped | Stand-by, running | Key re-cycle | 8 | 6010 | 8 |
| CONTROLLER MISM. | MC is not closed, EB is applied, Traction/Pump, valves stopped | Start-up | Install the correct software and Key re-cycle | 12 | FFEF | 239 |
| EEPROM KO | Controller works using default parameters | Start-up, stand-by, running | | 13 | 3610 | 208 |
| PARAM RESTORE | No effect | Start-up | Traction/Pump request | 14 | 3611 | 209 |
| SP MISMATCH xx | MC is opened, EB is applied, traction/pump stopped | Running | Key re-cycle | 15 | FFF2 | 242 |
| OUT MISMATCH xx | MC is opened, EB is applied, traction/pump stopped | Running | Key re-cycle | 16 | FFE3 | 227 |
| LOGIC FAILURE #3 | MC is opened, EB is applied, traction/pump stopped | Stand-by | Valves or Traction/Pump request | 17 | FF11 | 17 |
| LOGIC FAILURE #1 | MC is opened, EB is applied, traction/pump stopped | Stand-by, running | Valves or Traction/Pump request | 19 | 5114 | 19 |
| INPUT MISMATCH | MC is opened, EB is applied, Traction/Pump stopped | Start-up, standby, running | Key re-cycle | 58 | FFD5 | 213 |
| W.SET. TG-EB XX | Traction/Pump motor is stopped | Start-up, stand-by, running | Key re-cycle | 59 | FFD4 | 212 |
| NO CAN MSG. | MC is opened, EB is applied, Traction/Pump, valves stopped | 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, valves stopped | Stand-by | Key re-cycle | 71 | FFD2 | 210 |
| VDC LINK OVERV. | MC is not closed, EB is applied, Traction/Pump, valves stopped | Stand-by, running | Valves or Traction/Pump request | 77 | FFCA | 202 |
| WRONG ENC SET | MC is not closed, EB is applied, Traction/Pump, valves stopped | Start-up | Key re-cycle | 85 | FF51 | 201 |
| 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 stopped | Stand-by, running | Key re-cycle | 96 | FFFA | 237 |

### 10.2.1 Troubleshooting of alarms from supervisor μC

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

Cause:

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

Troubleshooting

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

**BUMPER STOP** *(MDI/LED code = 0)*

Cause

The two digital inputs dedicated to the bumper functionality are high at the same time. The alarm can occur only if parameter BUMPER STOP = ON and only if ACE2 is in CAN OPEN configuration (see parameter CONTROLLER TYPE in SPECIAL ADJUST. list, paragraph 8.2.4).

Troubleshooting
- Turn off one or both inputs dedicated to the bumper functionality.
- If the alarm occurs even if the inputs are in the rest position, check if the microswitches are stuck.
- In case the problem is not solved, replace the logic board.

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

Cause:

The software is not compatible with the hardware. Each controller produced is "signed" at the end of line test with a specific code mark saved in EEPROM according to the customized Part Number.
According with this "sign", only the customized firmware can be uploaded.

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

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

Cause:

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

Troubleshooting:

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

**INPUT MISMATCH** *(MDI/LED code = 58)*

Cause:

The supervisor microcontroller records different input values with respect to the master microcontroller.

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

**LOGIC FAILURE #1** *(MDI/LED code = 19)*
    Cause
This fault is displayed when the controller detects an undervoltage condition at the KEY input. Undervoltage threshold is 11V for 36/48V controllers and 30 V for 72/80V controllers.

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

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

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

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

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

    Troubleshooting
-    Verify the CANbus network (external issue).
-    Replace the logic board (internal issue).

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

    Troubleshooting
-    Verify the CANbus network (external issue).
-    Replace the logic board (internal issue).

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

    Troubleshooting:
-    Checks the matching of the parameters between Master and Supervisor.

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

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

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

## SP MISMATCH XX *(MDI/LED code = 15)*
Cause:
This is a safety related test. The master µC has detected a supervisor µC wrong set point. The hexadecimal value "XX" facilitates Zapi technicians debugging the problem.

Troubleshooting:
- Check the matching of the parameters between master and supervisor.
- Ask for assistance to a Zapi technician.
- If the problem is not solved, replace the logic board.

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

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

## VDC LINK OVERV. *(MDI/LED code = 77)*
Cause
This fault is displayed when the controller detects an overvoltage condition. Overvoltage threshold is 65 V for 36/48V controllers and 116 V for 80V controllers.
As soon as the fault occurs, power bridge and MC are opened. The condition is triggered using the same HW interrupt used for undervoltage detection, uC discerns between the two evaluating the voltage present across DC-link capacitors:
- High voltage → Overvoltage condition
- Low/normal voltage → Undervoltage condition

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

**W.SET. TG-EB** *(MDI/LED code = 59)*
    Cause:
Supervisor microcontroller has detected that the master microcontroller has imposed a wrong setpoint for TG or EB output.

    Troubleshooting:
- Check the matching of the parameters between master and supervisor.
- Ask for the assistance of a Zapi technician.
- If the problem is not solved, replace the logic board.

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

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

**WRONG ENC SET** *(MDI/LED code = 85)*
    Cause:
Mismatch between ENCODER PULSES 1 parameter and ENCODER PULSES 2 parameter (see paragraph 8.2.5).

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

**WRONG RAM MEM.** *(MDI/LED code = 71)*
    Cause:
The algorithm implemented to check the main RAM registers finds wrong contents: the register is "dirty". 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 SLAVE VER.** *(MDI/LED code = 91)*
    Cause:
Wrong software version on supervisor uC.

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

# 11 SPARE PARTS

| Part number | Description | ACE Version |
|---|---|---|
| C16589 | Protected 400 A strip UL Fuse. | 24V / 550A |
| C16587 | Protected 300 A strip UL Fuse. | 24V / 400 A<br>24V / 450A<br>36-48V / 400A<br>36-48V / 450A |
| C16588 | Protected 350 A strip UL Fuse. | 24V / 500A<br>36-48V / 500 A |
| C16586 | Protected 250 A strip UL Fuse. | 36-48V / 350A<br>80V / 350A |
| C16603 | Protected 200 A strip UL Fuse. | 96V / 300A |
| C16591 | Protected 175 A strip UL Fuse. | 80V / 250A<br>96V / 215A |
| C16520 | 10 A 20 mm Control Circuit Fuse | All |
| C29523 | SW 180 80 V<br>Single Pole Contactor | All |
| C29522 | SW 180 48 V<br>Single Pole Contactor | All |
| C12531 | Ampseal 23 pins female connector | All |
| C12372 | Connector Molex 8 pins Female | All |

# 12 PERIODIC MAINTENANCE

Check the wear and condition of the moving and fixed contactors contacts.
Electrical contacts should be checked every **3 months**.

Check the foot pedal or tiller microswitch. Using a suitable multi-meter, confirm that there is no electrical resistance between the contacts by measuring the voltage drop across the terminals. Switches should operate with a firm click sound. Microswitches should be checked every **3 months**.

Check the battery cables, cables to the inverter, and cables to the motor. Ensure the insulation is sound and the connections are tight.
Cables should be checked every **3 months**.
Check the mechanical operation of the pedal or tiller. Are the return springs ok? Do the potentiometers wind up to their full or programmed level?
Check every **3 months**.
Check the mechanical operation of the contactor(s). Moving contacts should be free to move without restriction.
Check every **3 months**.
Checks should be carried out by qualified personnel and any replacement parts used should be original. Beware NON ORIGINAL PARTS
The installation of this electronic controller should be made according to the diagrams included in this manual. Any variations or special requirements should be made after consulting a Zapi agent. The supplier is not responsible for any problem that arises from wiring methods that differ from information included in this manual.

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

Remember that battery-powered machines feel no pain.

**NEVER USE A VEHICLE WITH A FAULTY ELECTRONIC CONTROLLER.**

---

⚠️ *IMPORTANT NOTE ABOUT 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 types of waste materials.*
*Zapi commits itself to update its technology in order to reduce the presence of polluting substances in its products.*

---

# 13 APPENDICES

The goal of this chapter is to give the operator a general overview about the use of Zapi PC CAN Console and Zapi Smart Console.
The description focuses on the basic information about connection and settings.
For additional functionalities available for both tools, it is suggested to contact Zapi technicians in order to receive more detailed information or dedicated documentation.

## 13.1 Appendix A: PC CAN Console user guide

Windows Pc CAN Console uses standard Zapi communication protocol to display inverter information. It provides all standard Zapi Console functions with the easier handling of Windows environment. Besides, Pc CAN Console offers the possibility to save parameter configurations into a file and to restore them onto the control afterwards.
Before running Pc CAN Console, the user must install it launching "setup.exe".

### 13.1.1 PC CAN Console configuration

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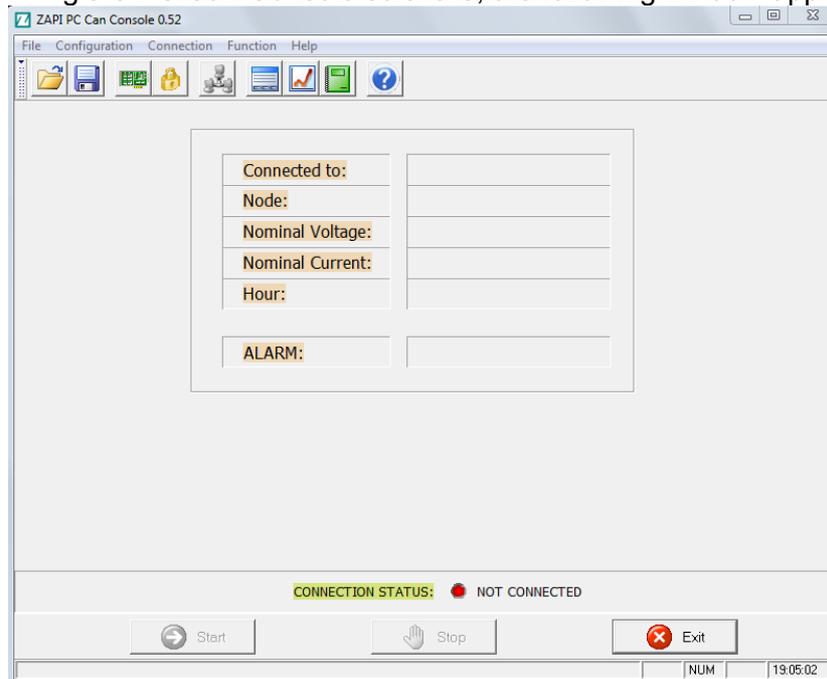


The first step to accomplish is to define the CAN device attached to the PC, so select the "Configuration" (Alt-C) → Can Device (Ctrl-C) menu or click on Can Device icon.
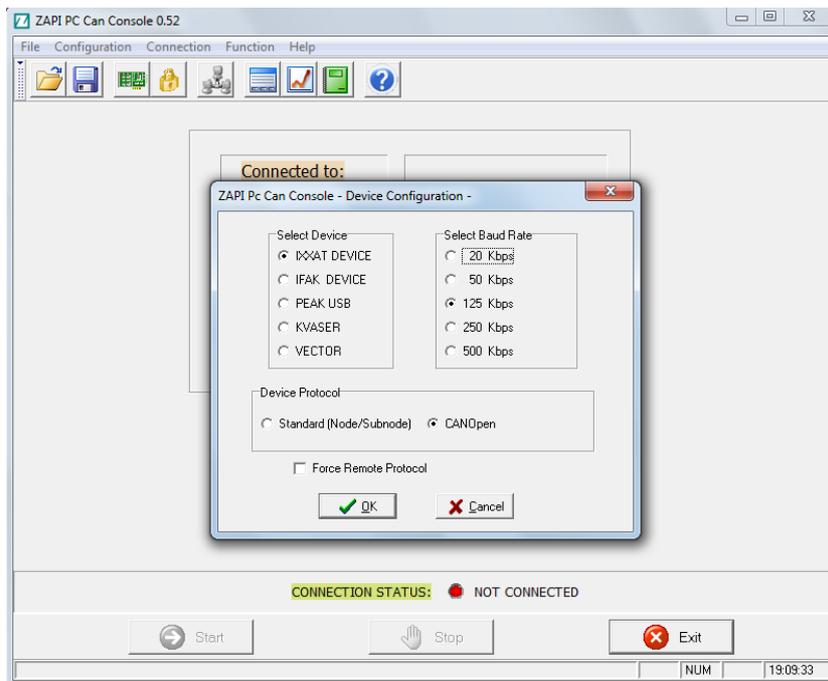
From this form you can define the CAN device in use (IXXAT, IFAK or Peak) and the CAN communication speed. Once you have defined the CAN interface, you have to choose which CAN device you want to connect to: choose "Connection" → "Set Node" (or press the "Set Node" icon).
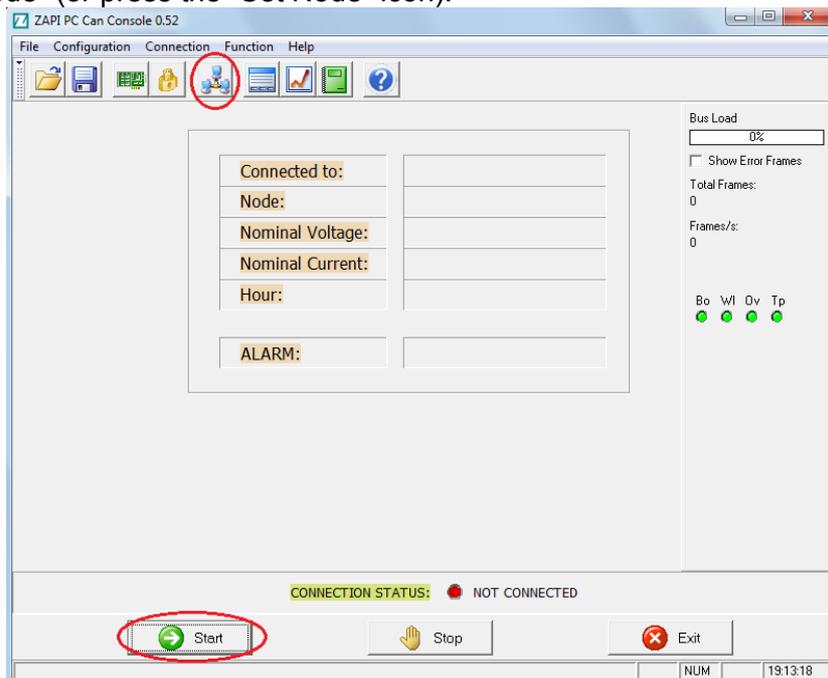


Once you have chosen the node you want to connect to, start the connection. Insert the password in order to have the possibility to change the parameters: choose "Configuration" → "Enter Password". Type the password: "ZAPI"

### 13.1.2 Parameter download

Once you are connected to the selected node, you need to download the inverter parameters: choose "Function" → "Parameter" menu (or press the "Parameter" icon).
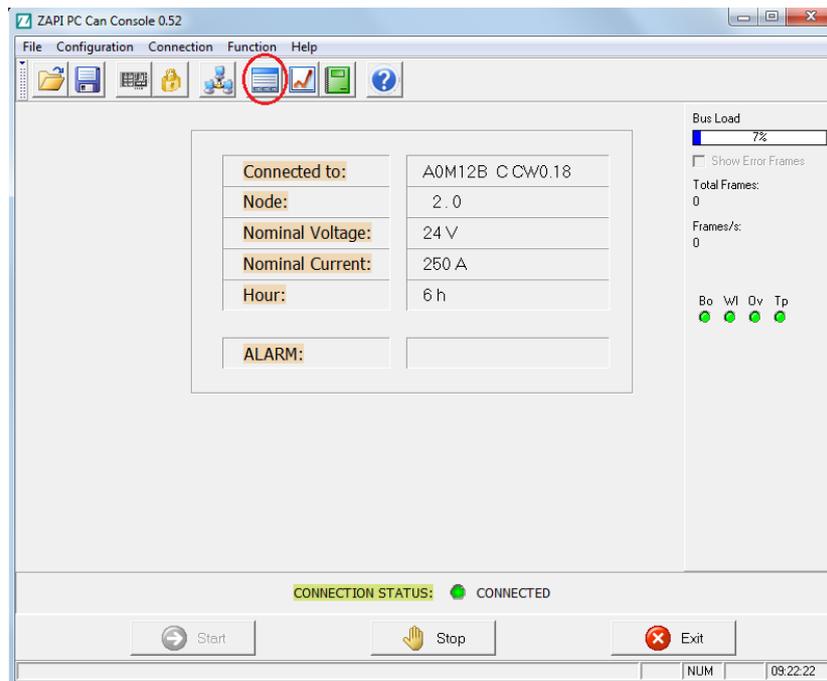
Then click on the "Receive" button: the parameters will be downloaded automatically.
When the parameters have been all received, you can change their values.

### 13.1.3 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 will be saved as a csv file in order to be opened with Microsoft Excel® or any other spreadsheet tool.
The file contains the whole list of parameter and for each one various data are available, in particular:

- Parameter value as it is saved within the controller ("Value" column).
- Parameter value as it is shown by console or similar tools ("Scaled Value" column).
- Name of the menu where parameter is placed ("Name menu" column).

File name is generated as a hexadecimal code of the time and date of saving.
This codification prevents any overwrite of previously saved files.
Once you have selected the menu inside that resides the parameter you want to change, it is possible to modify the value using the "+" and "–" buttons.
   Click on the "Store" button to save the changes on EEPROM.
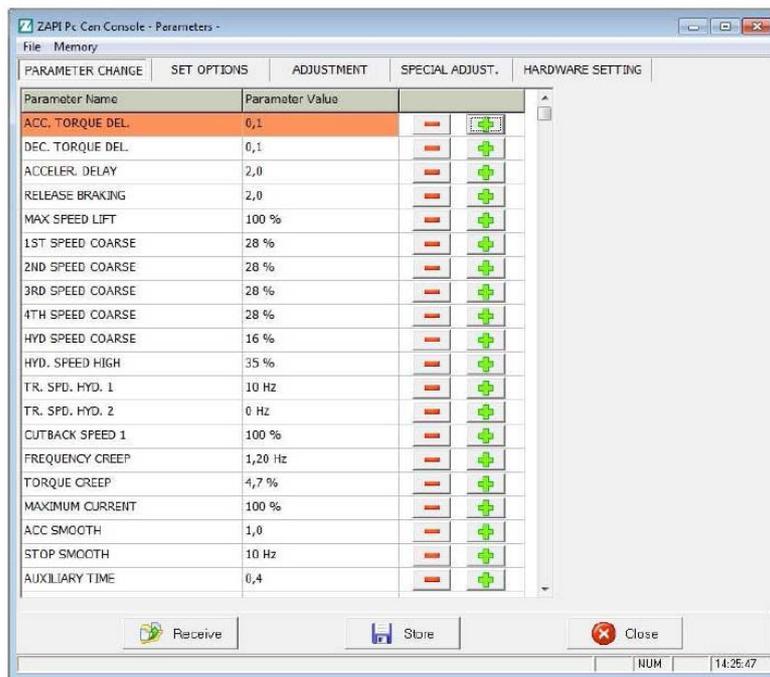
### 13.1.4  Program Vacc

Choose "Function" → "Program Vacc" menu.
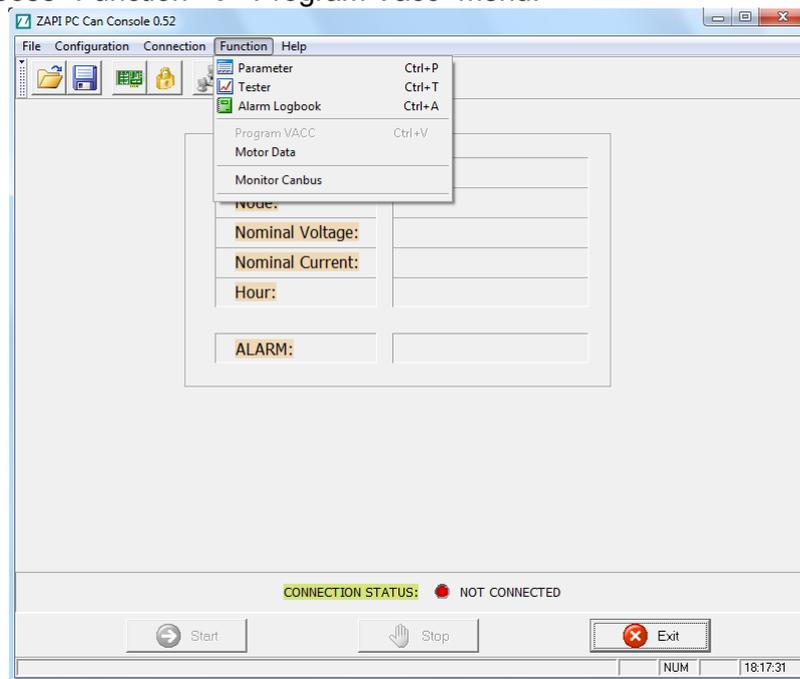


When "Acquire" is pressed, the PROGRAM VACC procedure starts:
- Select the Enable switch, if any;
- Select the direction switch (either forward or backward);
- Depress the pedal to its maximum excursion.
  Displayed values will vary accordingly to operator inputs.
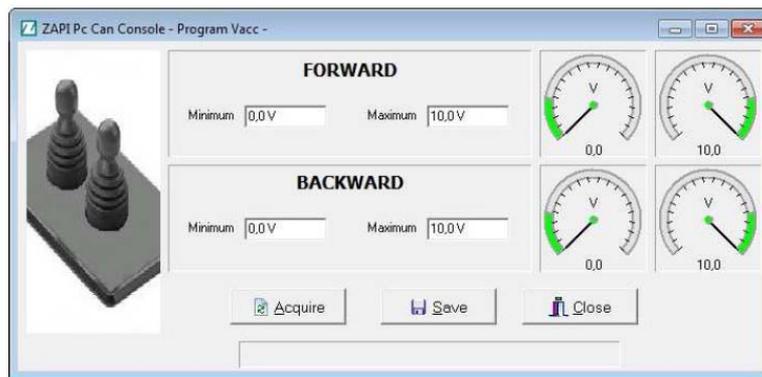
## 13.1.5 Lift & Lower acquisition

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, the acquisition will start:
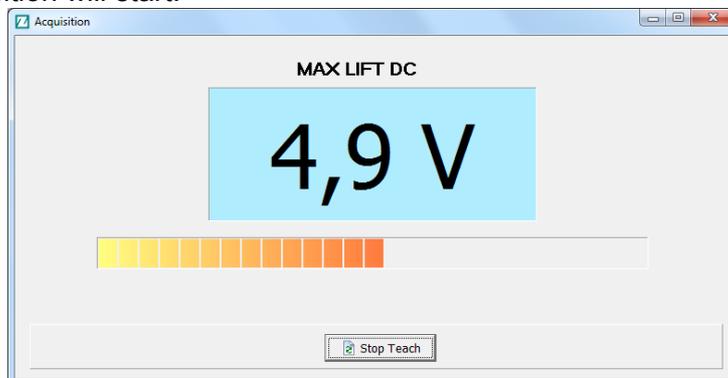


- Select the Enable switch, if any.
- Select the control switch (either lift or lower).
- Move the control sensor (lift/lower potentiometer) to the correct position according to what you are acquiring.
- Press "Stop Teach" button.

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

## 13.1.6 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.

### 13.1.7 TESTER functionality

From the main page you can also access to the TESTER function from the Function menu (Alt-u)→Tester (Ctrl-T) menu where you can check some inverter information.
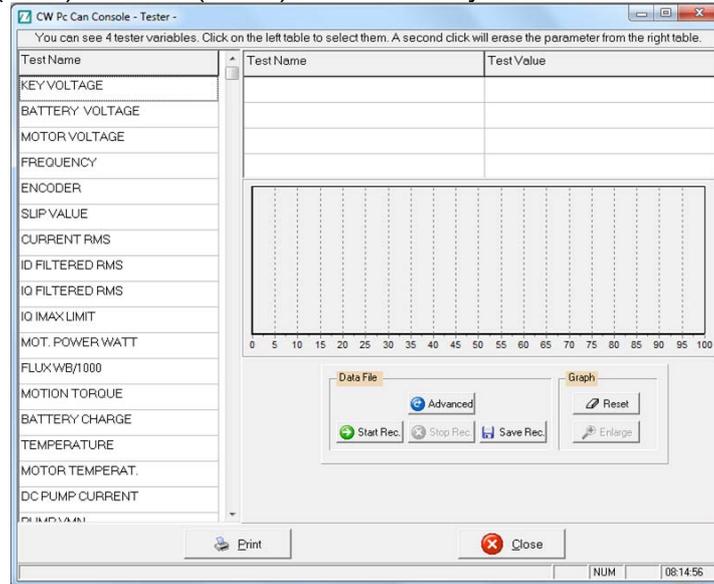


### 13.1.8 Alarm Logbook

This window will display the alarms stored in the controller.
For every alarm will be shown the working hour at which it's occurred, the motor temperature and the number of repetitions.
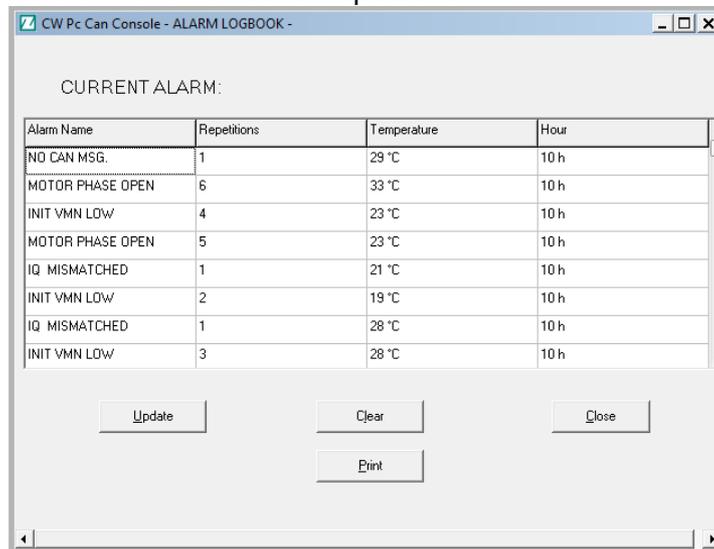


Four buttons are present:
Update → user can update alarm logbook;
Clear → user can clear alarm logbook on inverter EEPROM;
Close → closes the window;
Print → prints alarm logbook data on the selected printer.

## 13.2 Appendix B: Zapi Smart Console user guide



### 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 line and connect with any Zapi controller inside this line.
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 sees the entire CAN line and all CAN modules.

### 13.2.2 The keyboard

The keyboard is used to navigate through the menus. It features some keys with special functions and a green LED. Different button functions are shown below.

#### UP and DOWN keys

In most cases a menu is a list of items: these items are ordered in rows. The selected item is highlighted in light blue.
Up and down keys are used to move the selection up and down: in other words they are used to roll or scroll the menu.

#### LEFT and RIGHT keys

Normally used to increase and decrease the value associated with the selected item.

#### OK and ESC keys

OK key is used either to confirm actions or to enter a submenu.
ESC is used either to cancel an action or to exit a menu.

#### F1, F2, F3 keys

These buttons have a contextual use. The display will show which F button can be used and its function.

#### ON key

Used while operating with internal batteries.

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

#### Green LED

When the console is powered running the green LED is on.
Green LED can blink in certain cases which will be described better in the following sections.

### 13.2.3 Home Screen

After showing the Zapi logo, the HOME SCREEN will appear on the display:

```
*CONS AFG ZP015*

RS232 CONSOLE

CAN CONSOLE

AUTOSCAN CAN

CONSOLE UTILITIES

MENU CONSOLE


                    14:00
```
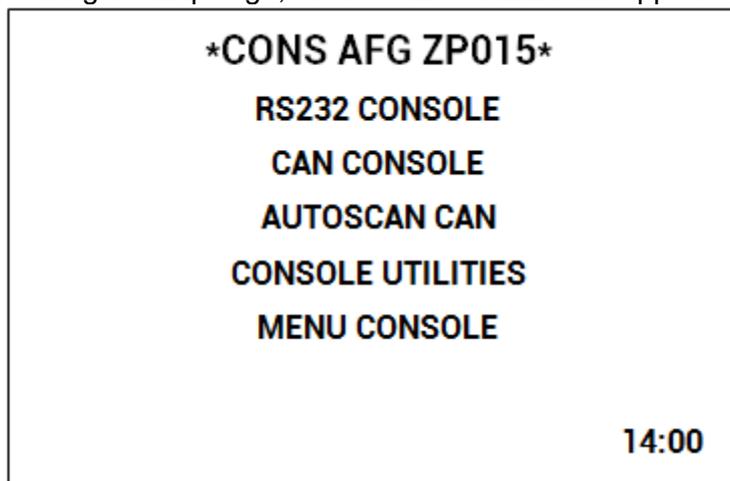
From top:
- First line tells which firmware version is running <u>inside the console</u>, in this case ZP 0.15.
- RS232 Console: enter this menu to start a serial connection as in the Console Ultra.

- 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 hour is shown at the bottom right.

Moreover, the green LED is on and still.

The "RS232" line is already highlighted at the 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 be shown after some seconds: press ESC key and look 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.*

## 13.2.4 Connected

If connection is successful, the display will show a page similar to the next one.

```
VMCM      ZP1.00
48V     0A    500h



NO CAN MSG N. 05
```
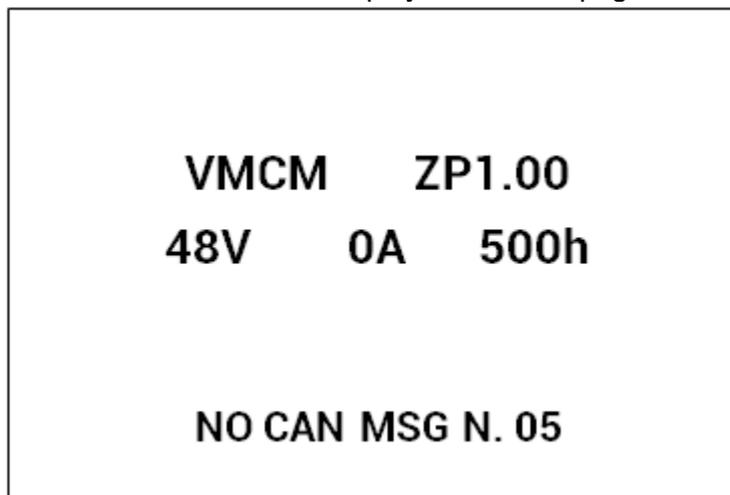
This menu shows basic information about the controller, in a similar way to the console Ultra.
- First line displays the controller firmware.
- Second line shows controller voltage, controller current and hour meter.
- Last line shows the current alarm code, if present.

Press OK to access the MAIN MENU.

```
* MAIN MENU *
PARAMETER CHANGE
TESTER
ALARMS
PROGRAM VACC
SAVE PARAMETERS
RESTORE PARAMETERS
SET MODEL
```

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

Use UP and DOWN keys to navigate the list: once you find the desired menu press OK to enter it.

### 13.2.5 How to modify parameters

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

```
PARAMETER CHANGE
ACCELER DELAY          1.0
E. ACCELER. DELAY      1.5
SPEED LIMIT BRK        2.2
E. SPD. LIMIT BRK      2.2
RELEASE BRAKING        4
E. RELEASE BRAKING     2.5
CURVE BRAKING          3
```

With UP and DOWN keys you can scroll the list: once you have highlighted the parameter you want to modify, press either LEFT or RIGHT keys to decrease or increase the parameter value.

*Keep LEFT/RIGHT button pressed to continuously repeat the value modification ("auto-repeat" function): this function will speed up the procedure in case many parameter values must be changed.*

You can press ESC to exit the menu at any time. In case parameters have been modified, the console will prompt the request to confirm/discard changes.

```
           PARAMETER CHANGE
ACCELER DELAY                   1.0
E.
        APPLY CHANGES?
S.
E.     YES=OK       NO=ESC
R.
E. RELEASE BRAKING             2.5
CURVE BRAKING                   3
```
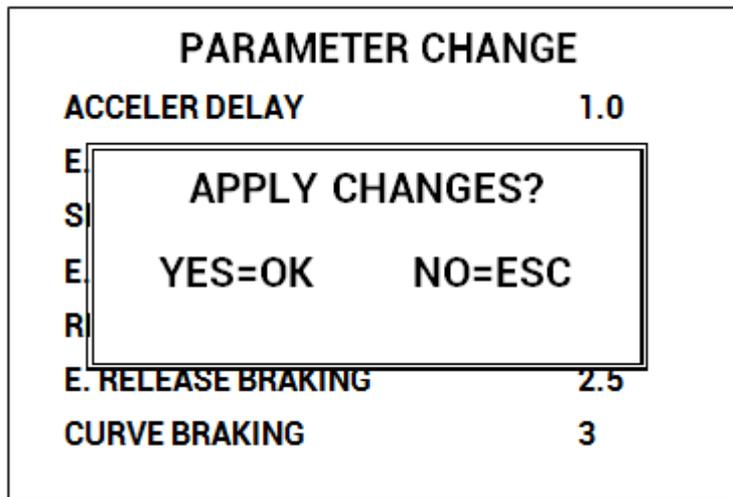
*Description above is valid for every menu which contains parameters and options like SET OPTIONS, ADJUSTMENT, HARDWARE SETTINGS, etc.*

### 13.2.6 PROGRAM VACC

PROGRAM VACC menu has been slightly modified from old consoles.
Upon entering this menu the console shows the current programmed values.

```
           PROGRAM VACC
           CURRENT VALUES
      MAX          5.0
      MIN          0.3




      PRESS OK FOR SETUP
```
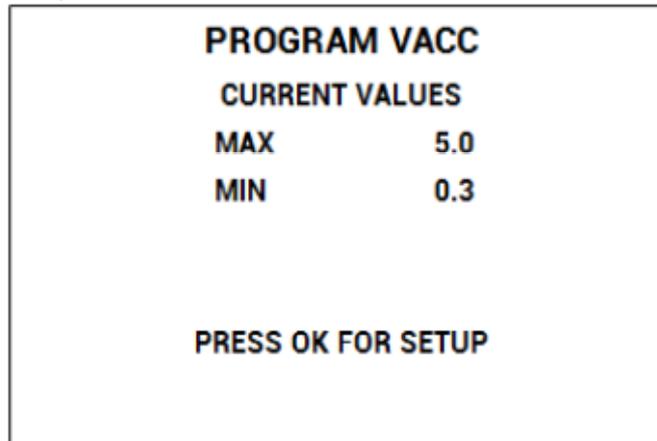
When OK is pressed, PROGRAM VACC procedure starts. Console invites you:
- to select the enable switch, if any;
- to select the direction switch (either forward or backward);
- to depress the pedal to its maximum excursion.

Displayed values vary accordingly to operator inputs.

*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, console asks if programmed values must be saved or discarded.

### 13.2.7 Lift and Lower acquisition

From MAIN MENU go into the Adjustment menu.
With UP and DOWN keys you can scroll the list: once you have highlighted a value you want acquire, press OK.
When OK is pressed, the procedure starts:
- select the Enable switch, if any;
- select the control switch if any (either lift or lower);
- move the control sensor (lift/lower potentiometer) to the correct position according to what you are acquiring.

Displayed values vary accordingly to operator inputs.

*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.*

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/discard changes.

PARAMETER CHANGE

ACCELER DELAY          1.0

APPLY CHANGES?

YES=OK          NO=ESC

E. RELEASE BRAKING     2.5
CURVE BRAKING          3
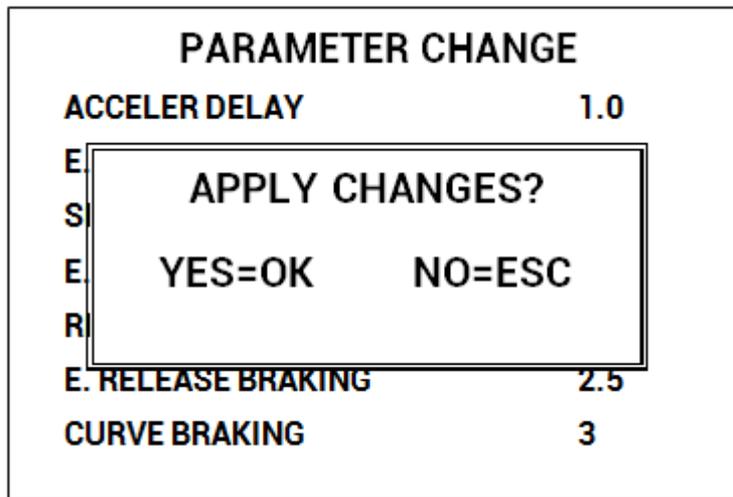
### 13.2.8 Steer acquisition

From MAIN MENU go into the Adjustment menu.
The procedure to follow is the same described in previous paragraph.

### 13.2.9 Tester

Compared to 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
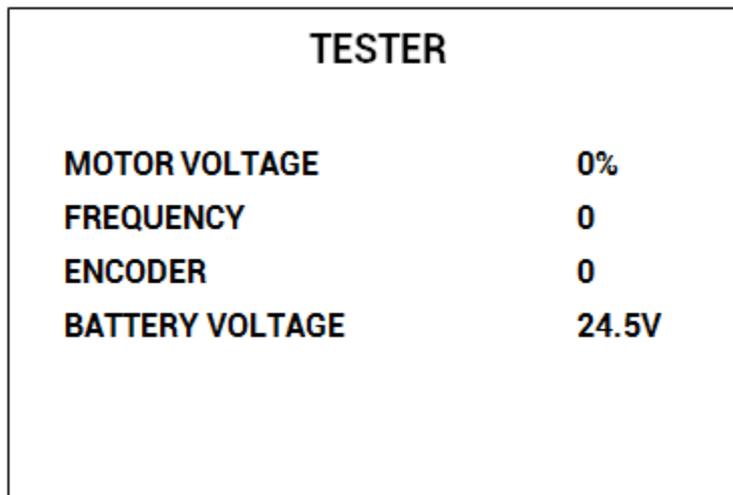
### 13.2.10   Alarms

ALARMS menu has changed from Console Ultra. Display shows all controller alarms at once.

```
                    ALARMS


    NO CAN MESSAGE              10h
    INCORRECT START             2h
    NONE                        0h
    NONE                        0h
    NONE                        0h
           F1 TO CLEAR LOGBOOK
```

*Five is the maximum number of alarm codes which is 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 pieces of information about that alarm are displayed.

Press F1 to clear the alarm logbook of the controller: once F1 is pressed, the console asks for confirmation.

## 13.2.11 Download parameter list into a USB stick

When Smart Console is connected to a controller, it has the possibility to download all parameters into a USB stick.

To use this function, go into the menu SAVE PARAMETER USB in 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 if it has been created with the PC CAN Console. Thus it contains the whole list of parameter and, for each one, various data are available, in particular:
- Parameter value as it is saved within controller ("Value" column).
- Parameter value as it is shown by console or similar tools ("Scaled Value" column).
- Name of the menu where parameter is placed tools ("Name menu" column).

File name is generated as an hexadecimal code of the time and date of save.

This codification prevents any overwrite of previously saved files.

### Download procedure

After entering SAVE PARAMETER TO USB, the Smart Console checks the presence of a USB stick. If the stick is not connected, it asks the operator to connect one.

When the stick is present, the display shows the content, starting from the root

directory (/) of the filesystem. Display looks like the following picture.

```
SAVE PARAMETERS USB

>/
  VMNCNA11
  COPY
  DOCUMENTS




    OK SAVE     ESC EXIT
  (< PREV DIR , > ENTER DIR)
```
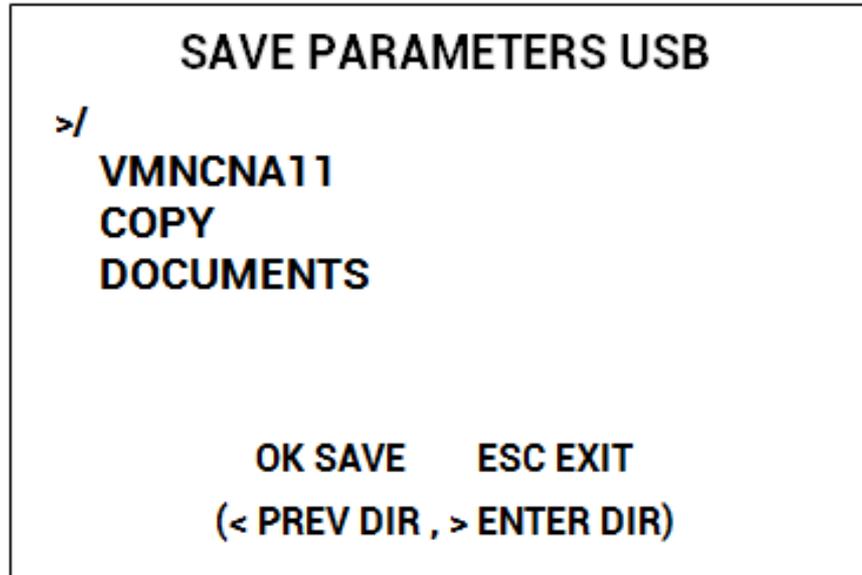
Notice that only directories are shown, not single files.
While exploring the content, the navigation buttons work in the following way:
- Up/down keys scroll the list.
- Right key explore the highlighted directory: its content (directories only) will be shown immediately.
- Left key returns one level back in the directory tree: it does not work in the root directory.
- Esc returns to HOME SCREEN.
- OK starts download.

When saving files, the console creates a subdirectory whose name has 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 parameter files are saved in the same location.
If the directory does not exist, it is created when download is carried out for the first time.

To download 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 parameter download. A progression bar shows the ongoing process.
4. When finished, press ESC so to return to MAIN MENU. USB stick can be removed safely.

Connect the USB stick to a PC and enter the directory of point 1). A subdirectory with the correct name and, inside this one, a csv file are present.

*During download the led blinks slowly to indicate the console is running.*

*When download has finished USB stick can be unplugged safely.*

***Do not remove USB stick during download or the file will result empty or corrupted.***