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EN

User Manual

ACE0 2µC
COMBIAC0 2µC

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NOTES DEFINITIONS

	This symbol is used in this publication to indicate an annotation or a suggestion you should pay attention to.
⚠	***This symbol is used inside this publication to indicate an action or a characteristic very important for security. Pay special attention to the annotations pointed out with this symbol.***

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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 ACE0/COMBIAC0 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 much effort to ensure that this document is complete and accurate at the time of printing. In accordance with Zapi policy of continuous product improvement, all data in this document are subject to change or correction without prior notice.

1.1.3 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 warning 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 equipment knowledge.

⚠ ***Before doing any operation, ensure that the battery is disconnected and when the installation is completed start the machine with the drive 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's Responsibility

Zapi motor controllers are intended for controlling motors in electric vehicles. These controllers are supplied to original equipment manufacturers (OEMs) for incorporation into their vehicles and vehicle control systems.
Electric vehicles are subject to national and international standards of construction and operation which must be observed. It is responsibility of the vehicle manufacturer to identify the correct standards and to ensure that the vehicle meets these standards. As a major electrical control component, the role of a Zapi motor controller should be carefully considered and relevant safety precautions taken. It has several features which can be configured to help the system integrator meeting vehicle safety standards.
Zapi does not accept responsibility for incorrect application of its products.

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

COMBIAC0/ACE0 inverters are controllers designed to control AC induction, BLDC and PMSM motors, in the range from 2 kW to 5 kW continuous power, used in a variety of battery-powered material handling trucks.
COMBIACE0 is designed to control series-wound DC motors too, typically employed as pump motor; AC and DC sections are combined in the same device.
Typical applications include, but are not limited to: walkie trucks and rider pallet trucks, stackers, low level order pickers, small counterbalanced trucks, aerial-access equipment.

The main inverter features are:

- 16-bits microcontroller for motor control and main functions, 576+ kByte embedded flash memory.
- 16-bits microcontroller for safety functions, 320+ kByte embedded flash memory.
- Controller for AC motors from 2 kW to 5 kW.
- Pump controller for series-wound DC motors (only for COMBIAC0).
- Field-oriented motor control.
- Smooth low-speed control and zero-speed holding control.
- Zapi patented sensorless and sense-coil control.
- Driver for a line contactor.
- Low-side and high-side drivers for an electromechanical brake (short circuit protected).
- Drivers for PWM voltage-controlled electrovalves and for two proportional valves (PWM current controlled).
- Short-circuit and open-load protection.
- Thermal cutback, warnings and automatic shutdown for protection of motor and controller.
- ESD-protected CAN bus interface.
- Software downloadable via serial link (internal connector) or CAN bus (external connector).
- Diagnostic provided via CAN bus using Zapi PC CAN Console.
- Rugged sealed housing and connectors meet IP65 environmental sealing standards for use in harsh environments.

2.2 Technical specifications

Motor type: .... induction AC, synchronous AC, brushless DC
Control mode: .... speed or torque control
Operating frequency of the AC inverter: .... 8 kHz
Operating frequency of the DC chopper (COMBIAC0 only): .... 16 kHz
Ambient operating temperature range: .... -40 °C ÷ 40 °C
Ambient storage temperature range: .... -40 °C ÷ 85 °C
Maximum inverter temperature (at full power): .... 85 °C
Connector: .... 35-pins Ampseal
Package environmental rating: IP65

2.3 Current ratings

Model	Nominal DC voltage	Maximum 2-min rated current [Arms]	Continuous rated current [Arms]	DC maximum current [A]
ACE0	24V	220	110	-
	36/48V	180	90	
COMBIAC0	24V	220	110	270
	36/48V	180	90	220
ACE0 PW	*24V*	*320*	*160*	-
	36/48V	280	140	
	36/48V	320	140	
	80V	200	100	
COMBIAC0 PW	24V	320	160	400
	36/48V	280	140	300
	36/48V	320	140	300
	80V	200	100	200

Combinations of DC choppers and 3-phase inverters different from those reported in the previous table are also available.

Internal algorithms automatically reduce the maximum current limit when heat sink temperature is above 85°C. Heat sink temperature is measured internally near the power MOSFETs (see paragraph 6.6).

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

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

2.4 Voltage ratings

Nominal DC voltage	24V	36/48V	80V
Conventional working voltage range	19.2 V ÷ 28.8 V	28.8 V ÷ 57.6 V	57.8 V ÷ 96 V
Non-operational overvoltage limits	35V	65V	115V
Non-operational undervoltage limits	10V	10V	30V

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

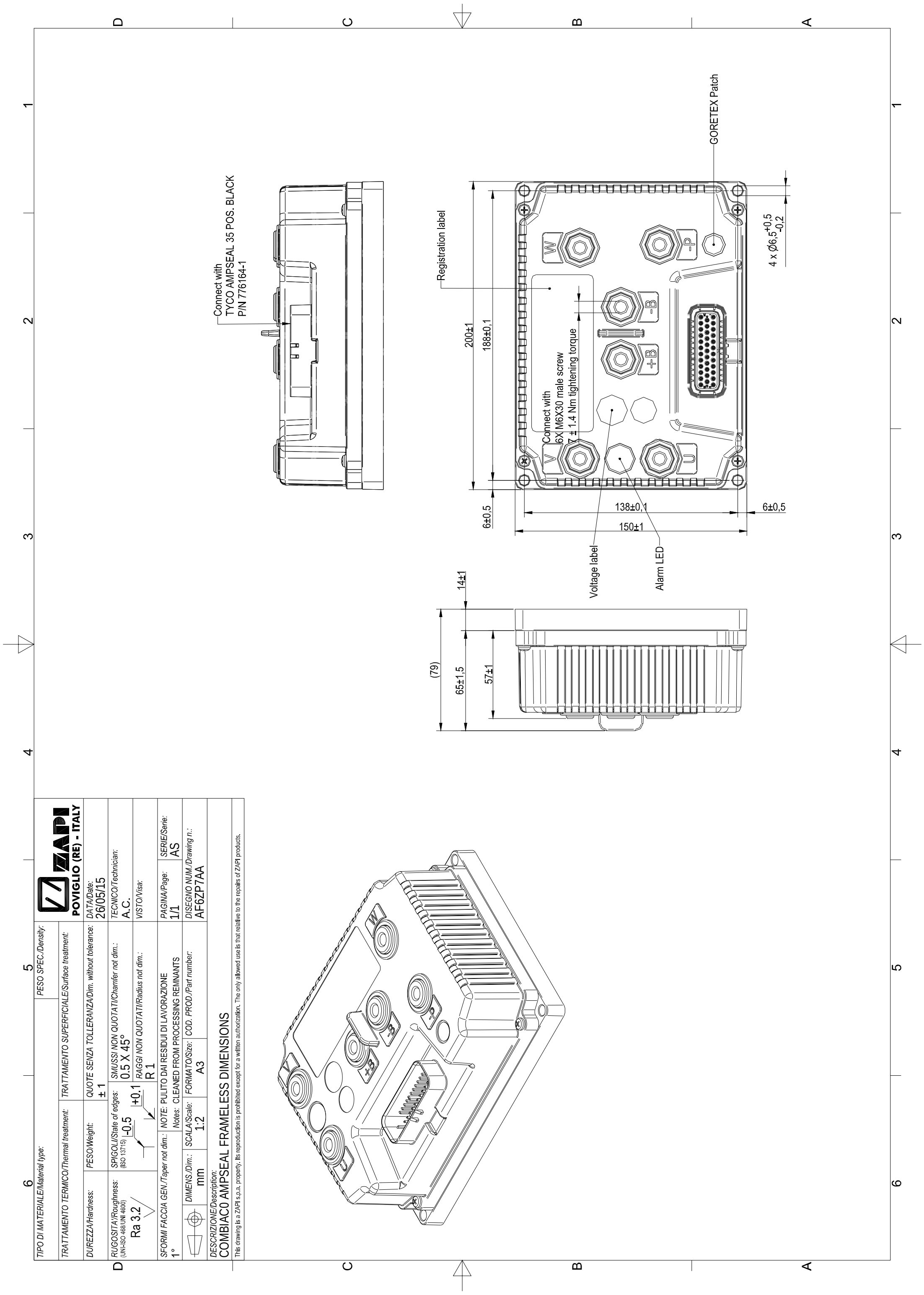
Undervoltage and overvoltage thresholds are defined by hardware. After start-up, controller is fully operative if the supply voltage stays within these limits.

Undervoltage is evaluated on the KEY input (A10); overvoltage is evaluated on the positive battery terminal +B.

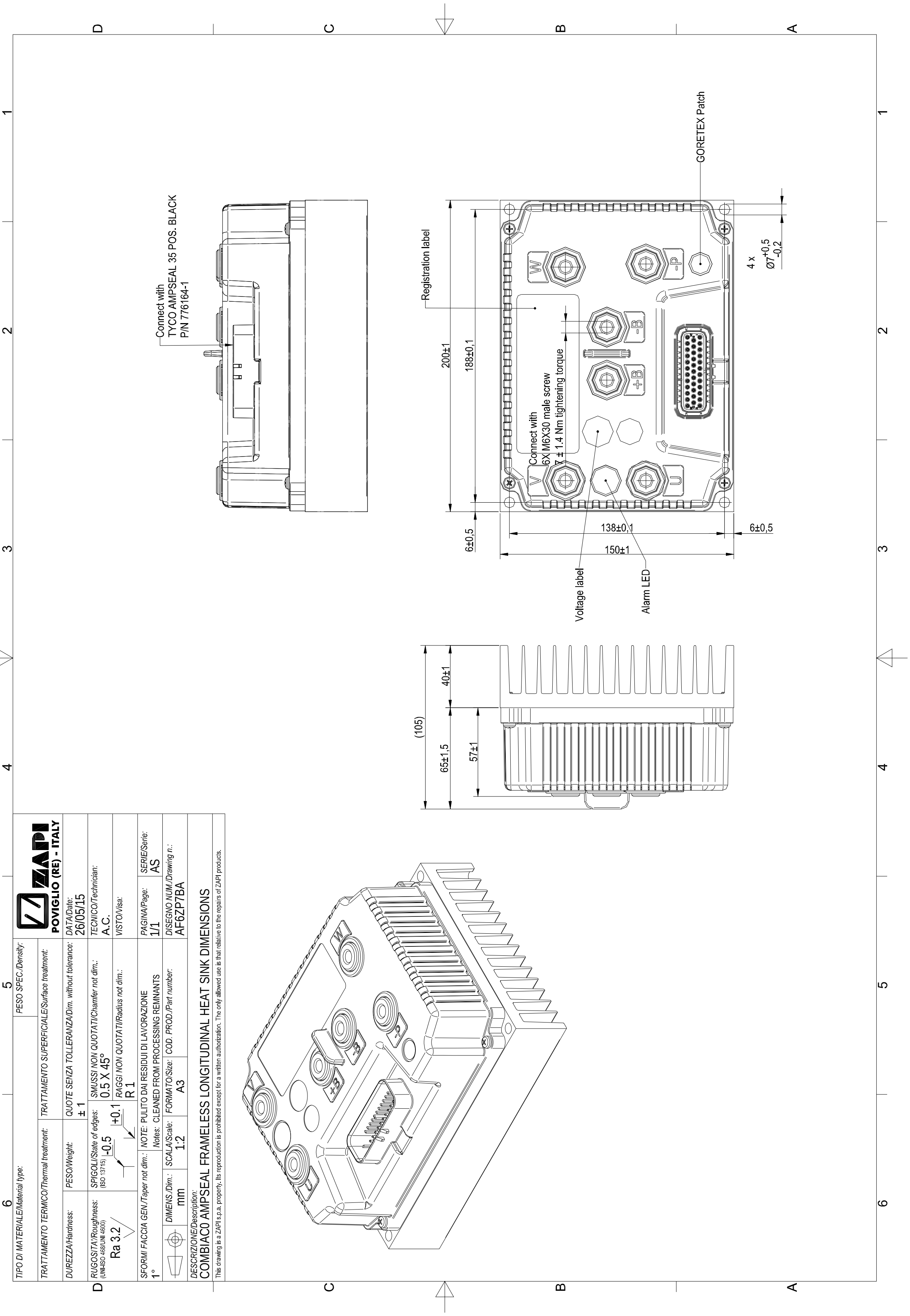
3 DRAWINGS

3.1 Mechanical drawings

3.1.1 Base plate version

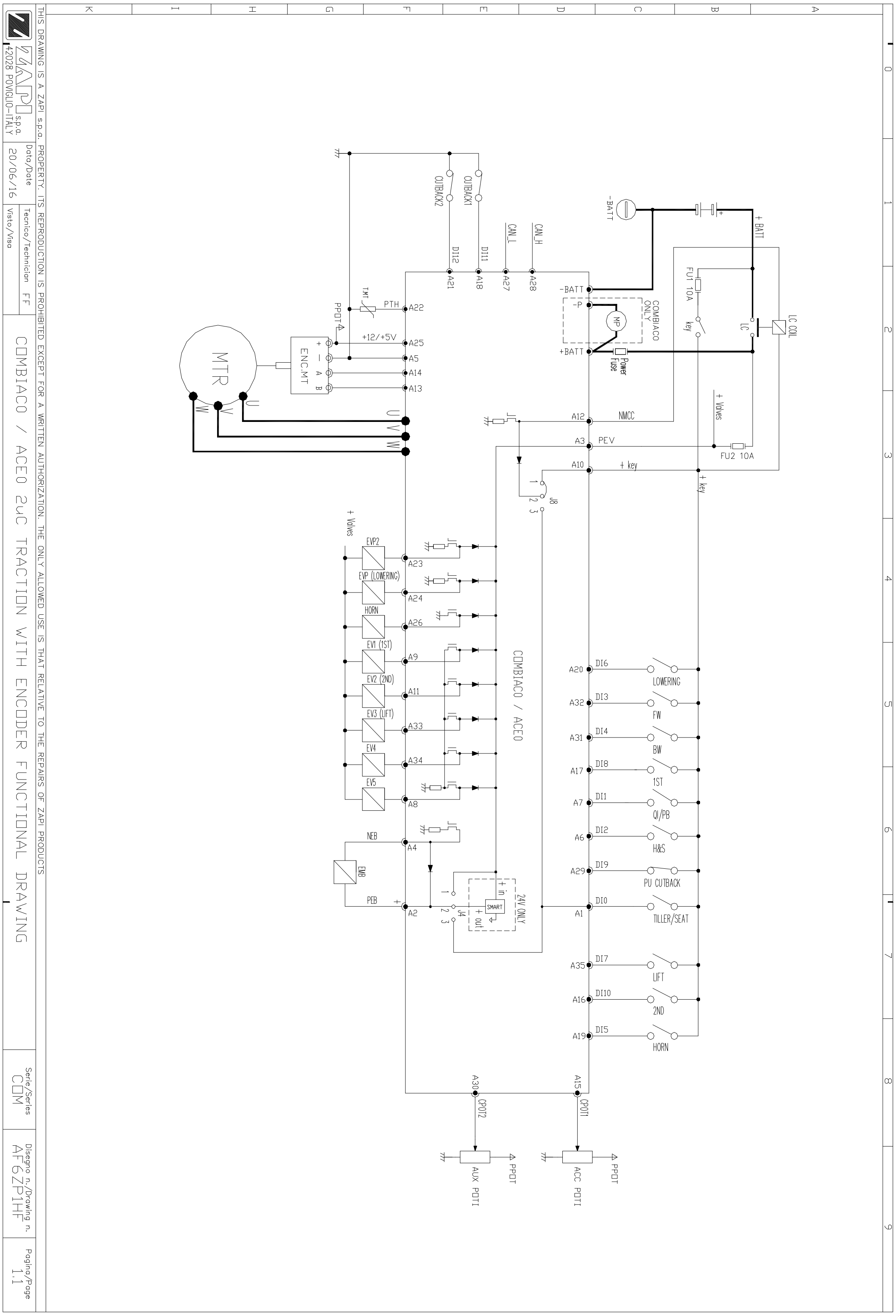


3.1.2 Longitudinal heat sink version

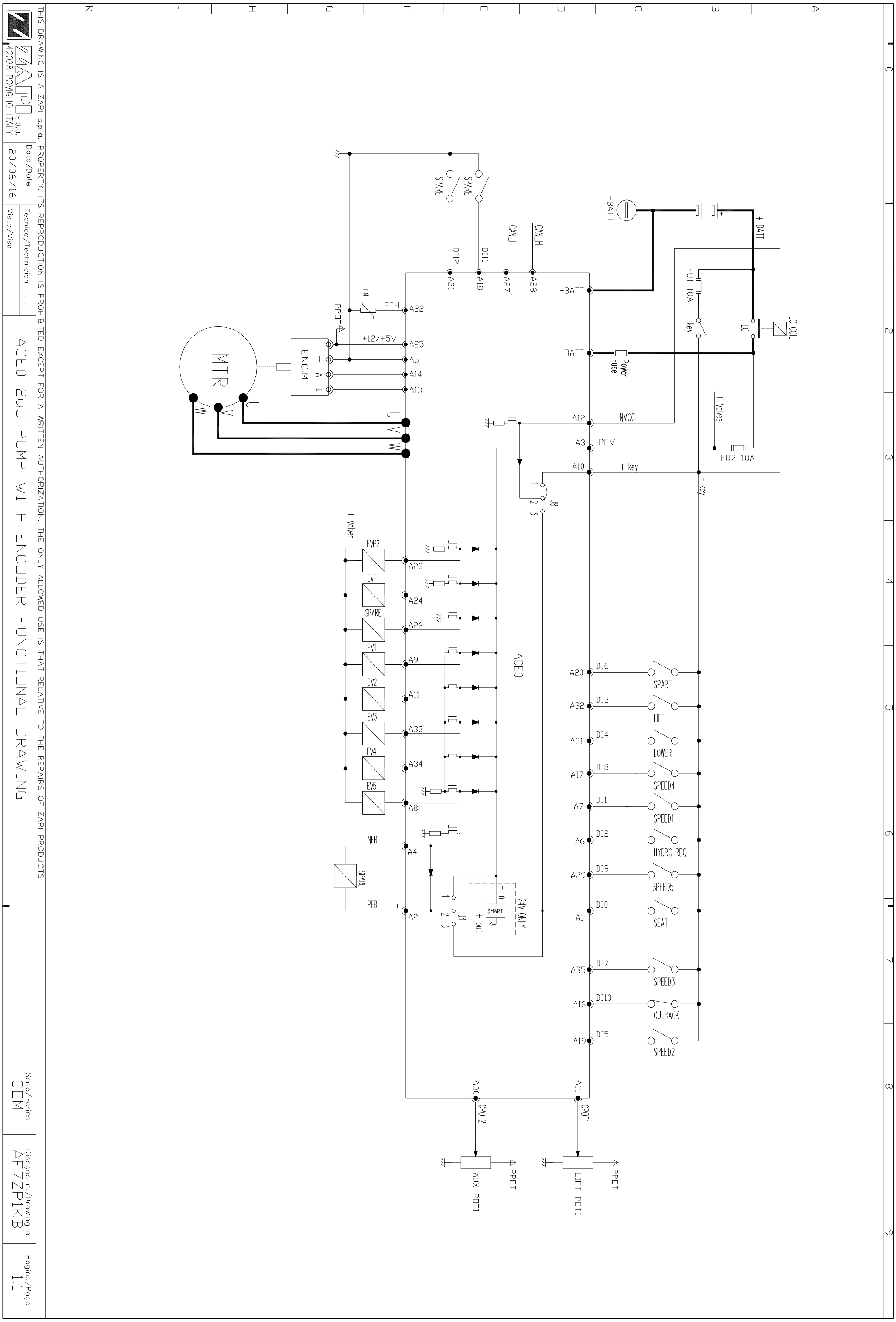


3.2 Connection drawings

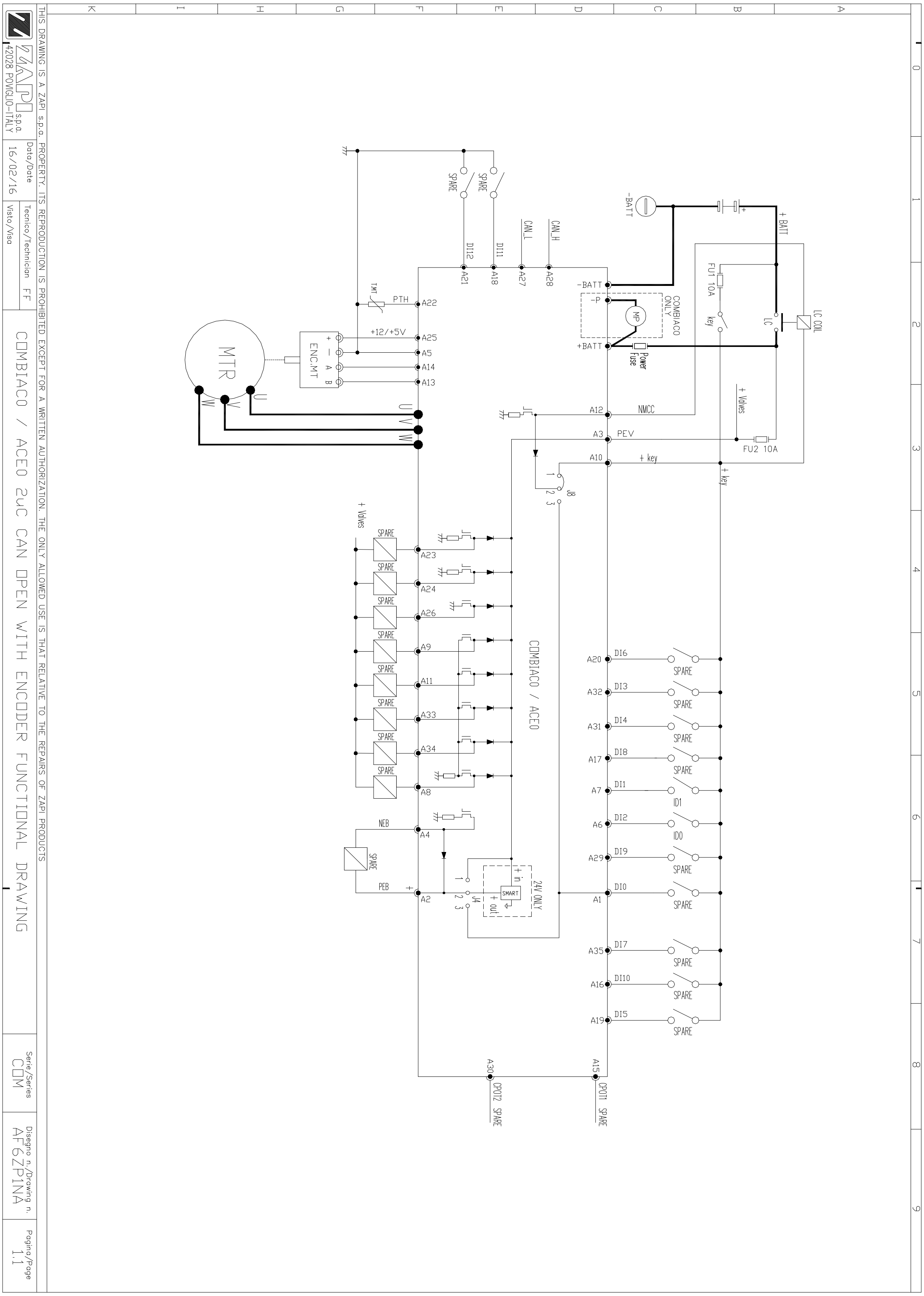
3.2.1 AC Traction configuration



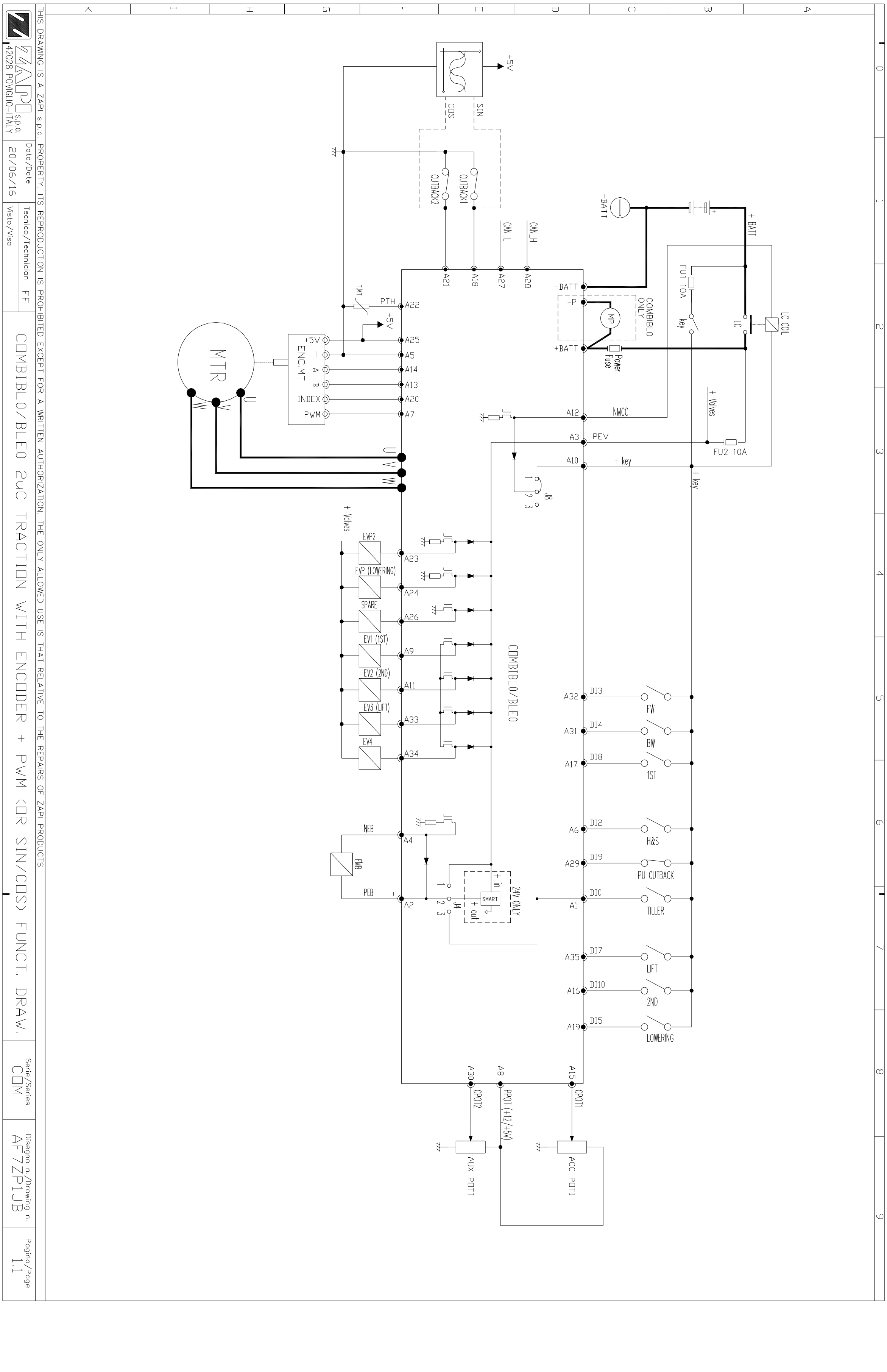
3.2.2 AC Pump configuration



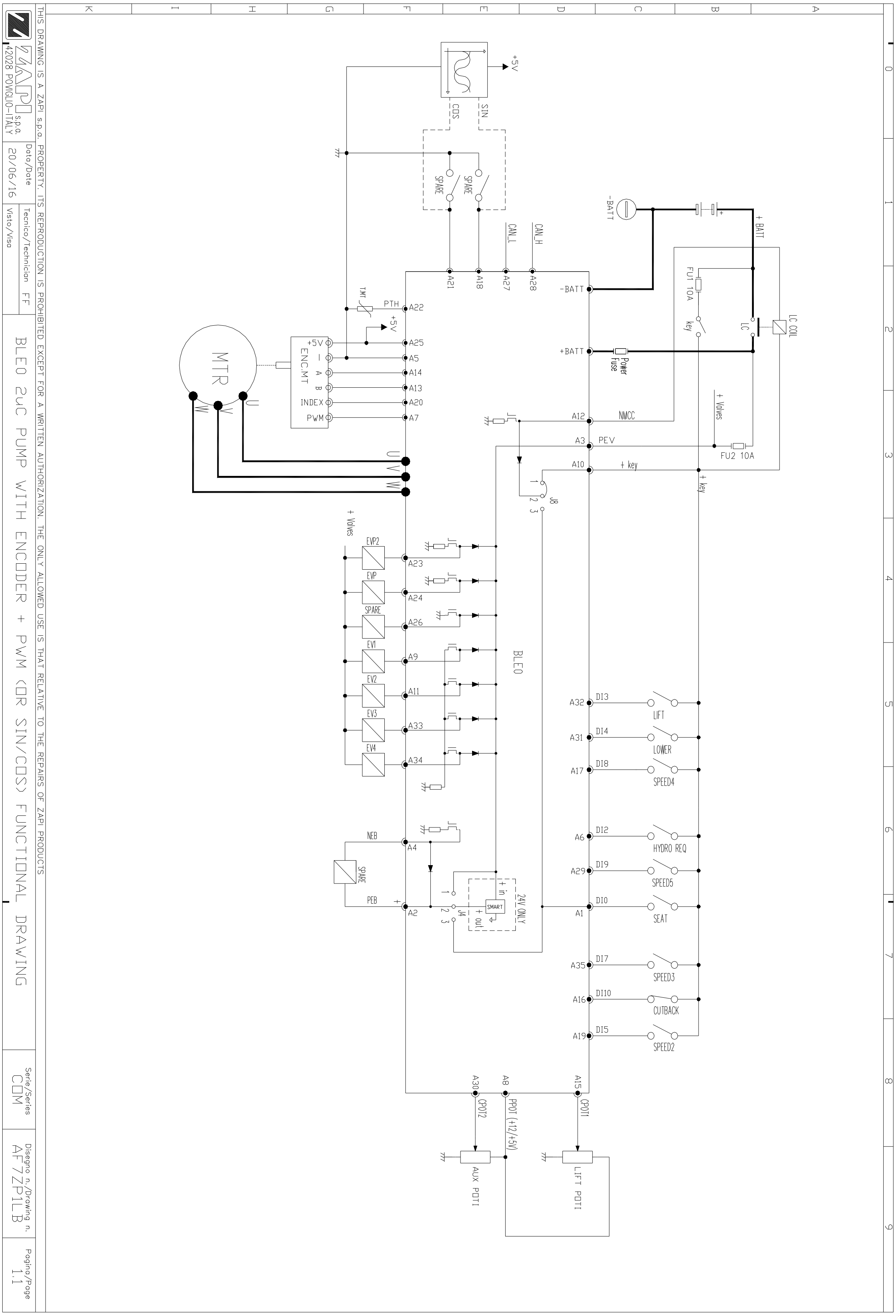
3.2.3 AC CAN Open configuration



3.2.4 PMSM Traction configuration



3.2.5 PMSM Pump configuration



4 I/O INTERFACE DESCRIPTION

4.1 Power connectors

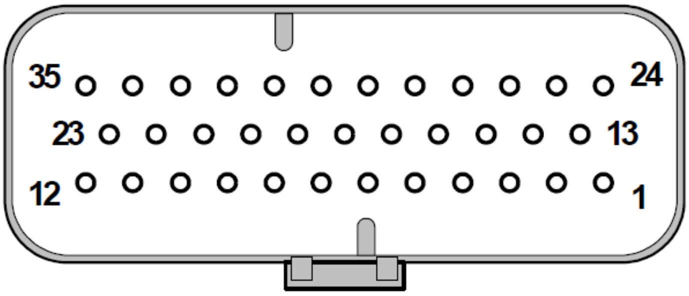
Power connections are on vertical posts where to bolt power-cables lugs. On the cover of the converter they are labeled as:

Terminal name	Description
+B	Positive battery termination
-B	Negative battery termination
U, V, W	Motor phase terminations.
-P	Negative terminal of pump DC motor (COMBIAC0 only).

In combination with COMBIAC0, DC pump motor must be connected between terminals +B and -P. PWM frequency at -P is 16 kHz. Terminal -P is protected by short circuit detection, voltage and current measurements. Freewheeling diodes to +B are built in (MOSFETs internal diodes).

4.2 Ampseal connector

Inverter is equipped with a 35-poles Ampseal connector like that of the figure. Each of the 35 pins is referred to as "A#", where "A" denotes the connector name and "#" the pin number, from 1 to 35.



35-poles Ampseal connector.

The following table lists the functional associations for the pins of the 35-poles Ampseal connector.

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

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

Pin	Type	Name	Description
A1	Input	DI0	Digital input DI0. The input is activated when it is connected to +B. With the logic hardware properly configured it can be used to supply the positive terminals of EB and MC. The default function is as TILLER input.
A2	Output	PEB	Positive supply of the electromechanical brake. For the 24V version only, it is supplied through a high-side driver.
A3	Input	PEV	Positive supply of electrovalves: EV1, EV2, EV3, EV4, EV5, EVP1, EVP2, HORN. With the hardware properly configured, it can be used to supply the positive terminal of EB. This input is to be supplied with positive voltage taken after main contactor.
A4	Output	NEB	Driving output for the electromechanical brake (driving to -B); PWM controlled; 2 A maximum continuous current.
A5	Output	NENC	Negative supply for external devices (encoder, potentiometers, etc.)
A6	Input	DI2	Digital input DI2. The input is activated when the external switch is closed. By default, if HARD & SOFT option is ON (see 8.2.2**Errore. L'origine riferimento non è stata trovata.**), the H&S function is activated when the switch is closed.
A7	Input	DI1	Digital input DI1. Active high. The input is activated when it is connected to +B. The default function is as QI/PB input (quick inversion/pedal brake). Closing the switch quick inversion function is activated.
A8	Output	EV 5 / PPOT	Driving output for the on/off electrovalve EV5; 1 A maximum continuous current (driving to -B). Depending on internal jumper configuration it can be used as positive supply for external devices (+12V/+5V, max150 mA).
A9	Output	EV1	Driving output for the on/off electrovalve EV1 (driving to -B); 1 A maximum continuous current.
A10	Input	KEY	Input of the key switch signal.
A11	Output	EV2	Driving output for the PWM voltage-controlled electrovalve EV2 (driving to -B); 1 A maximum continuous current.
A12	Output	NMC	Driving output for the main contactor (driving to -B); PWM voltage-controlled; 1 A maximum continuous current.
A13	Input	ENCB	Phase B of the traction motor encoder.
A14	Input	ENCA	Phase A of the traction motor encoder.

Pin	Type	Name	Description
A15	Input	CPOT1	Analog input 1. The default function is as accelerator reference (wiper contact of the accelerator potentiometer).
A16	Input	DI10	Digital input DI10. The input is activated when it is connected to +B. The default function is as 2ND input, closing the switch valve EV2 is activated.
A17	Input	DI8	Digital input DI8. The input is activated when it is connected to +B. The default function is as 1ST input, closing the switch valve EV1 is activated.
A18	Input	DI11 / CPOT3	Digital input DI11. The input is activated when the external switch is closed to -B. The default function is as CUTBACK SPEED 1 input. In the sense coil version, this input is connected to the AC motor sense coil. Hardware can be properly configured as additional analog or digital input.
A19	Input	DI5	Digital input DI5. The input is activated when it is connected to +B. The default function is as HORN input. Closing the switch, the horn is activated.
A20	Input	DI6	Digital input DI6. The input is activated when it is connected to +B. The default function is as LOWERING input.
A21	Input	DI12 / CPOT4	Digital input DI12. The input is activated when the external switch is closed to -B. The default function is as CUTBACK SPEED 2 input. In the sense coil version, this input is connected to the AC motor sense coil. Hardware can be properly configured as additional analog or digital input.
A22	Input	PTH	Analog input for the thermal sensor of the traction motor. Internal pull-up consists of a fixed 2 mA (max 5 V) current source.
A23	Output	EVP2	Driving output for the second PWM current-controlled electrovalve (driving to -B).
A24	Output	EVP1	Driving output for the first PWM current-controlled electrovalve (driving to -B). Default function is as LOWERING valve.
A25	Output	PENC	Positive supply for external devices (encoder, potentiometers, etc.) +12 /+5 V, 150 mA maximum.
A26	Output	HORN	Driving output for the horn electrovalve (driving to -B). Protected.

Pin	Type	Name	Description
A27	Output	CANL	Low-level CAN bus line.
A28	Output	CANH	High-level CAN bus line.
A29	Input	DI9	Digital input DI9. The input is activated when the external switch is opened. The default function is as LIFT DC CUTBACK input.
A30	Input	CPOT2	Analog input for the lift/lower potentiometer. If PEDAL BRK ANALOG = ON this input is used as analog brake input. If AUX POT. TYPE is different from 12; this input is used as reference for the lowering proportional valve.
A31	Input	DI4	Digital input DI4. The input is activated when it is connected to +B. The default function is as BW request. Closing this input truck moves backward.
A32	Input	DI3	Digital input DI3. The input is activated when it is connected to +B. The default function is as FW request. Closing this input truck moves forward.
A33	Output	EV3	Driving output for the PWM voltage-controlled electrovalve EV3 (driving to -B); 1 A maximum continuous current.
A34	Output	EV4	Driving output of the on/off electrovalve EV4 (driving to -B); 1 A maximum continuous current.
A35	Input	DI7	Digital input DI7. The input is activated when it is connected to +B. The default function is as LIFT enable input.

4.3 Internal connector

Pin	Type	Name	Description
1	-	-	Not used: it can be unconnected.
2	Input	NCLRXD	Negative serial reception.
3	Output	PCLTXD	Positive serial transmission.
4	Output	NCLTXD	Negative serial transmission.
5	Output	GND	Negative console power supply.
6	Output	+12	Positive console power supply.
7	Input	FLASH	It must be connected to pin 8 for flashing the code.
8	Input	FLASH	It must be connected to pin 7 for flashing the code.

4.4 External devices

4.4.1 Key Input

KEY input (A10) 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 the 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

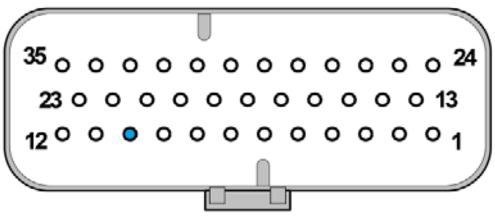
The KEY input is protected against reverse polarity with a diode and it has got approximately 22 nF of capacitance to -B for ESD protection and other filtering elements. This capacitance may give a high current spike at the KEY input depending on the external circuit.
Fuse FU1 (see functional drawings, paragraph 3.2), should be sized according to the number of motor controllers connected to it (10 A fuse is recommended) and the current absorption of the KEY input (input power below 15 W).

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

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

Connector position

A10.



4.4.2 Digital inputs

Digital inputs are meant to work in the voltage range from -B to +B. The related command devices (microswitches) must be connected to +B (typically to the key voltage) or to -B, 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, BW, PB, etc.) are 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 for digital inputs in standard Zapi configuration are listed in the following table. Custom hardware may feature different voltage values.

Inverter voltage	24 V	36/48 V	80 V
Logic low threshold	1.8 V	6 V	6 V
Logic high threshold	4.4 V	13.5 V	13.5 V
Voltage range	0 V ÷ 35 V	0 V ÷ 65 V	0 V ÷ 115 V

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

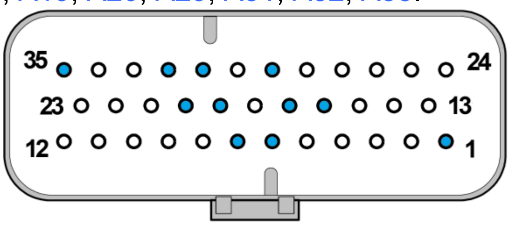
Protection
Each digital input has a 22 nF capacitor to -B for ESD protection.

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

Inverter voltage	24 V	36/48 V	80 V
Input impedance	4.5 kΩ	14.5 kΩ	30 kΩ

Digital inputs DI1, DI2, DI5, DI6, DI7, DI8, and DI9 are normally configured to be activated when closed to +B. Their behavior can be changed by special HW configuration, as to be activated when closed to -B.

Connector position
A1, A6, A7, A16, A17, A19, A20, A29, A31, A32, A35.



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

4.4.3 Analog inputs

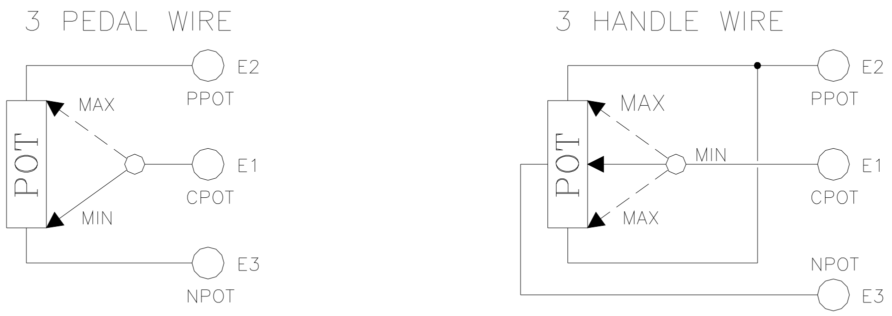
Analog inputs are for functions such as accelerator or brake references and they are acquired through a 10-bits analog-to-digital converter (resolution is given by the voltage excursion over 1024 levels).

Circuit

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

Inverter voltage	24 V, 36/48 V	80 V
Input impedance	99 kΩ	143 kΩ
Maximum frequency	13 Hz	10 Hz

The standard connection for the potentiometer is that on the left side of 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 next figure: potentiometer at rest in the middle, still in combination with a couple of travel-demand switches.



Potentiometer configuration

Negative supply of the potentiometer is to be taken from A5 (GND).
Potentiometer resistance should be in the 0.5 kΩ – 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 the console (see paragraphs 9.1, 9.2 and 9.3).

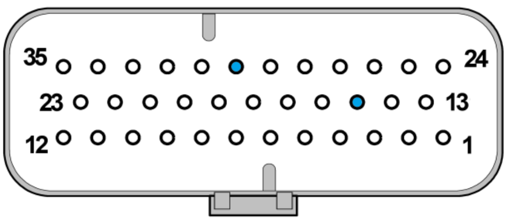
Analog inputs may also be used as extra digital inputs. In such a case, the digital input state is derived by SW from the ADC result. For example, a proximity switch supplied from +B could be connected to an analog input.

Protection

Analog inputs are protected against short circuits to +B and -B. Each one has a 22 nF capacitor to -B for ESD protection.

Connector position

A15, A30.



⚠ ***If an analog input is used as a speed feedback, a system safety strategy must be defined.***

⚠ ***The application software takes care of analog input errors such as VACC OUT OF RANGE or VACC NOT OK. See paragraph 10.3.***

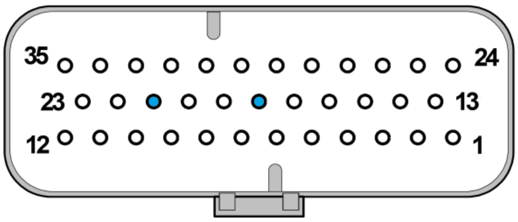
4.4.4 Special inputs

Special inputs normally configured as digital inputs active to -B are available on pins A18 and A21. It is possible to configure them differently in order to get two additional digital inputs active to +B or two additional analog inputs (electrically compatible with standard digital or analog inputs).

A proper hardware configuration permits to transform A18 and A21 in an interface for a sense-coil or for an absolute sin/cos sensor (PMSM) for special applications that use brushless motor. For more details about sensor installation see also paragraphs 5.2.5, 5.2.6.

Protection
Each special input has a 22 nF capacitor to -B for ESD protection.

Connector position
A18, A21.



4.4.5 Encoder inputs

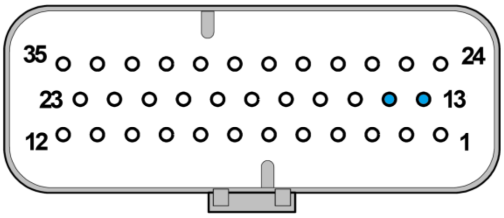
Inputs for motor-speed feedback (encoder signals) have an internal 1 kΩ pull-up for open-collector sensor output. Threshold levels are listed below.

Supply voltage	5 V	12 V
Logic low	1.4 V	6.4 V
Logic high	3.5 V	4.3 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
A13, A14.



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

For more details about encoder installation see also paragraph 5.2.4.

Note: encoder resolution and motor pole pairs are specified in the Console home page, which shows a headline like the following:

A0MT2B ZP1.13

Where:
A0MT: ACE0 traction controller (M stands for "Master μC", S for "Slave μC")
(A0MP: ACE0 pump controller)
2: motor poles pair 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

Encoder resolution can be changed through the dedicated parameters. See paragraph 8.2.5.

4.4.6 MC output

Main (or line) contactor is operated through an open-drain PWM voltage-controlled output on pin NMC A12.
In order to utilize the built-in free-wheeling diode, the coil must be supplied with the key voltage, like pin KEY A10 (see chapter 3.2).
A special hardware configuration allows to utilize a built-in free-wheeling diode connected to pin DI0 A1.
In case the vehicle design does not allow usage of the built-in freewheeling diode, i.e. if the return path integrity cannot be guaranteed in all situations, an external diode must be applied between the coil terminals.

Output features

- 1 A continuous current (holding).
- 2 A peak (pulling current) for a maximum of 200 ms.
- Individual hardware for detection of: shorted driver, open driver, open coil.
- 1 kHz default PWM frequency.

– Configurable output voltage, by means of two dedicated 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. However, if a different PWM frequency has to be used it is suggested to discuss it with Zapi technicians.

Protection

Protected against inductive discharge with internal freewheeling diode to the positive supply pin (A10 or A1, depending on the hardware configuration) and ESD protected by means of a suppressing device. Protected against reverse polarity of the battery.

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

Refer to chapter 10 more details about alarms.

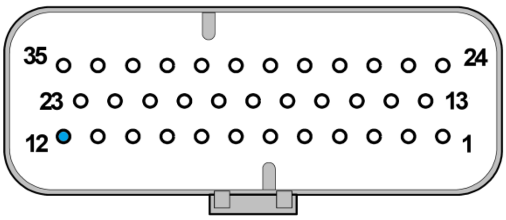
Overcurrent protection is featured by hardware and it is shared with EB output.

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

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

Connector position

A12.



To protect the controller from overvoltage caused by an inductive load, freewheeling diode to the positive supply pin (A10 or A1, depending on the hardware configuration) is built-in.

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

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

4.4.7 EB output

Electromechanical brake is operated through an open-drain PWM voltage-controlled output on pin NEB A4. In order to utilize the built-in freewheeling diode, the coil must be supplied with pin PEB A2 (see chapter 3.2).

For the 24V versions only, A2 is supplied by a smart high-side driver (see paragraph 4.4.9). For the other versions, A2 may be supplied either by pin DI0 A1 or by pin PEV A3 depending on the hardware configuration.

In case the vehicle design does not allow the usage of the built-in free-wheeling diode, i.e. if the return path integrity cannot be guaranteed in all situations, external free-wheeling diodes must be applied over the inductive loads supplied by the open drain outputs.

Output features

- Up to 22 A continuous current (holding current).
- Up to 3 A peak (pulling current) for a maximum of 200 ms.
- Individual hardware for detection of: shorted driver, open driver, open coil.
- 1 kHz PWM frequencies.
- Configurable output voltage, by means of separate parameters for pulling and holding stages.

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

Protection

Protected against inductive discharge with internal freewheeling diodes to pin A2 and ESD protected by suppressor device.
Not protected against reverse polarity of the battery. A way to avoid a failure caused by the polarity inversion is to activate the contactor only when the voltage over the DC-bus capacitors has reached the accepted pre charge level.
Built-in diagnostics:

- Overcurrent
- Driver shorted
- Driver open
- Coil open

Refer to chapter 10 for more details about alarms.

Overcurrent protection is featured by hardware and it is shared with MC output.

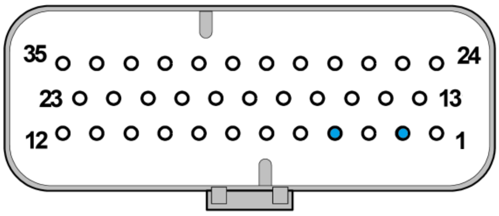
*EB output can be only a PWM voltage-controlled output. It **cannot** be used as current-controlled output.*

For version different from 24V, it is suggested to discuss with Zapi technicians about the supply of pin A2.

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

Connector position

A2, A4.



To protect the motor controller from overvoltage at inductive load, internal freewheeling diode to pin A2 is built-in.

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 Auxiliary outputs

Open-drain outputs can be used for operating services such as relays, hydraulic valves, horn, etc.
They work in different modes depending on the hardware structure:

- On/off (EV1, EV4, EV5, and HORN).
- PWM current controlled (EVP1, EVP2).
- PWM voltage controlled (EV2, EV3).

In order to utilize the built-in free-wheeling diodes, the loads must be supplied from pin A3 (see paragraph 3.2).
In case the vehicle design does not allow the usage of the built-in free-wheeling diodes, i.e. if the return path integrity cannot be guaranteed in all situations, external free-wheeling diodes must be applied over the inductive loads supplied by the open drain outputs.

ON/OFF outputs features

- Up to 1 Arms continuous (hold current) and max 2 A peak (pull current) for a maximum duration of 200 ms.
- Individual hardware for EV1 for driver shorted and driver open detection.

HORN output has not feedback hardware circuit. Any fault diagnosis is not available but an self-protected driver is used

PWM Voltage controlled Outputs features

- Up to 1 Arms continuous (hold current) and max 2 A peak (pull current) for a maximum duration of 200 ms.
- Individual hardware for driver shorted and driver open detection.
- 1 kHz PWM frequencies. It is applied to all PWM outputs.
- Each PWM voltage controlled outputs can be modified with separate software parameters.

PWM Current controlled Outputs features

- Up to 1.5 Arms continuous (hold current) and max 1.7 A peak.
- Individual hardware for driver shorted, driver open and coil open detection
- Self-protected against overload condition.
- Dithering feature thanks to a low amplitude current modulation at high frequency (see paragraph 8.2.4).
  Dithering is typically used when controlling proportional valves in order to create microscopic movements in the valve to prevent it from "sticking". Successful dithering improves the valve response for small changes.

  Dithering frequency is available in fixed steps:
  20.8, **22.7**, **25.0**, **27.7**, **31.2**, **35.7**, **41.6**, **50.0**, **62.5**, **83.3**.

  Dithering current amplitude can be adjusted up to 13% of reference value. Actual dithering amplitude is dependent on load inductance.

Protection

The auxiliary outputs are protected against inductive discharge with internal freewheeling diodes on pin A3.

The auxiliary outputs are not protected against reverse polarity of the battery. A way to avoid a failure caused by the polarity inversion is to activate the contactor only when the voltage over the DC-bus capacitors has reached the accepted pre charge level (see picture in section 3.2).

Built-in diagnostics:
- Overcurrent;
- Shorted driver;
- Open driver;
- Open coil (only for PWM current-controlled outputs).
-

Refer to section 10 for more details.

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

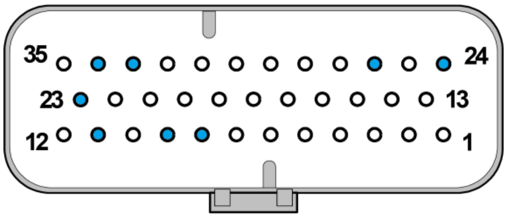
The shunt resistor for overcurrent protection is shared among EV1, EV2, EV3, EV4 and EV5 output. The overcurrent threshold is fixed by hardware to 9 A.

The maximum total continuous current when outputs EV1, EV2, EV3, EV4, and EV5 are active at the same time is 3 A. The maximum total peak current is 9 A.

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

Connector position

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



To protect the motor controller from overvoltage at inductive load, internal free-wheeling diodes are mounted to the A3 pin.

Please ensure that inductive loads are 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 fan or other loads with built-in capacitor can give high inrush current when turn ON which will give an Open Drain over current trip. The inrush current must be below the open-drain peak current.

4.4.9 High-side driver

For 24 V versions, it is also available a high-side switch for critical functions providing redundancy to turn OFF the EB.
If the open drain EB output is short circuited, it is possible to turn OFF the High side switch to disconnect load.
The High side switch has maximum output current 3 A. The high side switch (smart driver) has only ON/OFF control and it is present only on 24 V versions.

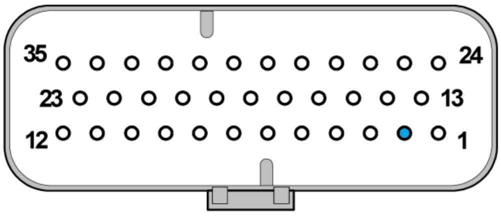
Protection

Internal hardware short circuit protection.

Built-in diagnostics:
- Shorted driver
- Open driver

Refer to section 10 for more detailed description.

Connector position
A2



4.4.10 Motor temperature measurement input

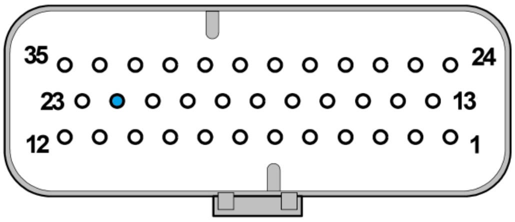
Input for motor-temperature sensor, for measuring the temperature of motor windings, is available on pin PTH A22.
Compatible temperature sensors are like:

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

On/Off.

Protection
PTH 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
A22



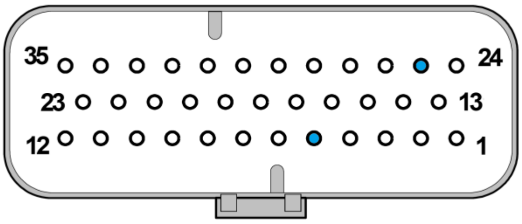
4.4.11 Sensor supply

Supply for external motor-speed sensors.
Output voltage is configurable via hardware by internal jumper to +12V or +5V; total maximum output current is 100 mA.

Actual values for "+12V" and "+5V" are respectively 13.1 V ± 0.5 V and 5 V ± 0.3 V.

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

Connector position
GND A5, +12/+5V A25.



4.4.12 Analog supply

A second supply for external analog sensors and analog speed or brake

potentiometers is available on pin A8 in substitution of EV5 output.
Output voltage is configurable via hardware by internal jumper to +12V or +5V; maximum output current is 100 mA.

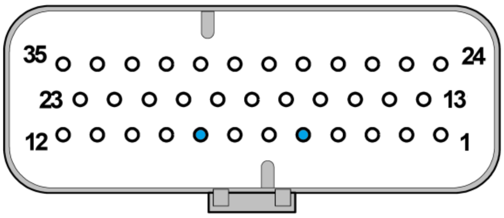
Actual values for "+12V" and "+5V" are respectively 13.1 V ± 0.5 V and 5 V ± 0.3 V.

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

GND A5, PPOT (+5/+12) A8.



4.4.13 CAN bus

CAN bus interface is available for communication with the controller, featuring:

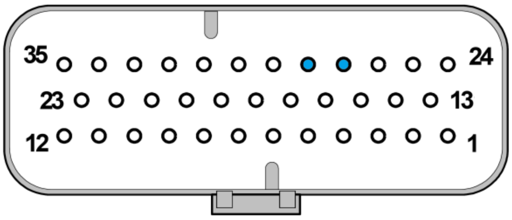
- Physical Interface according to ISO 11898-2.
- Data rate can be 125, 250 or 500 kbit/s.
- CAN driver is +5 V supplied and provides a rail to rail signal on the differential output (CANH - CANL).
- An internal 120 Ω termination resistor can be built-in.
- Common-mode filter (resistors and capacitor)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

Protection

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

Connector position

CANL A27, CANH A28.



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

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

5 INSTALLATION HINTS

This section presents a general procedure for startup and verification of ACE0/COMBIAC0 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 having proper section. The screwing torque for the controller power connection must be comprised in the range 5.6 Nm ÷ 8.4 Nm. For the optimum inverter performance, the cables to the battery should be run side by side and be as short as possible.

5.1.2 Contactors

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 10.5. 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 Ω – 100 Ω between terminals +B and -B of the inverter.***

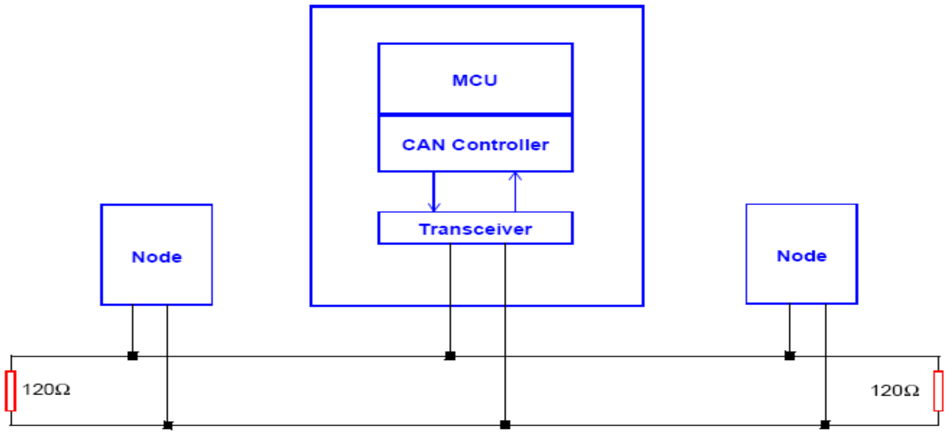
5.2.1 Positioning and cooling of the controller

Install the inverter with the base-plate on a flat, clean and unpainted 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.

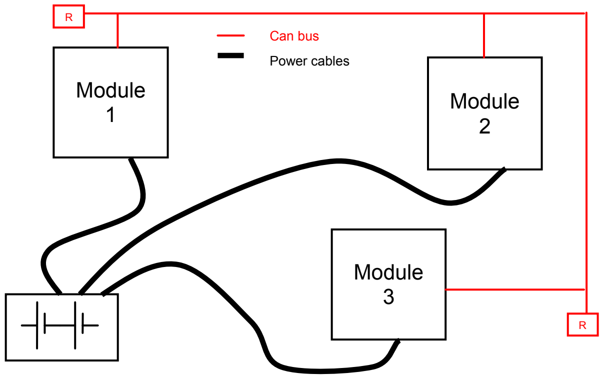
5.2.2 Wirings: CAN bus connections and possible interferences

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.



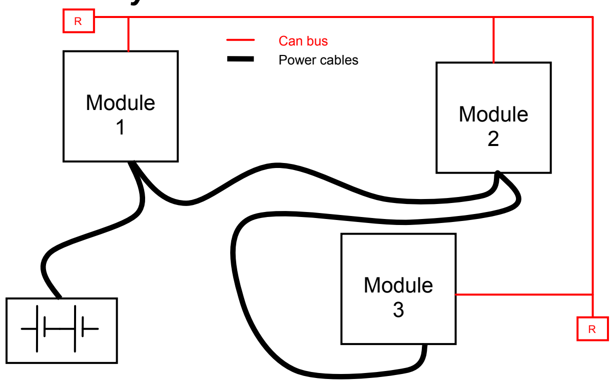
- The best type of cables for CAN bus connections is the twisted pair; if it is necessary to increase the immunity of the system to disturbances, a good choice would be to use shielded cables, where the shield is connected to the frame of the truck. Sometimes it is sufficient a not shielded two-wire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

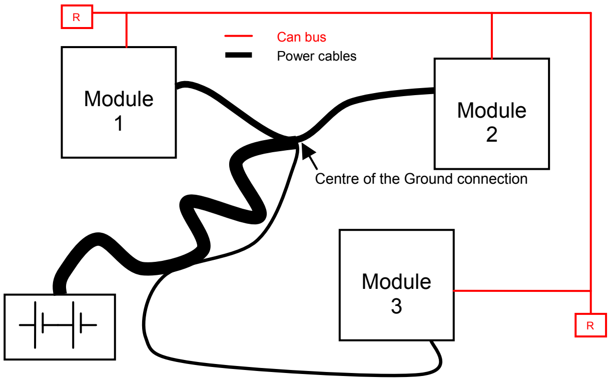
Correct Layout:



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).

5.2.3 Wirings: I/O connections

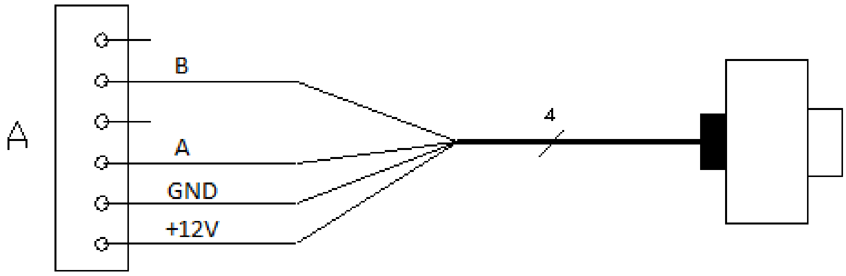
- After crimping cables, verify that all strands are entrapped in the wire barrel.
- Verify that all crimped contacts are completely inserted in the connector cavities.
- For information about pin assignment, see chapter 4.

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

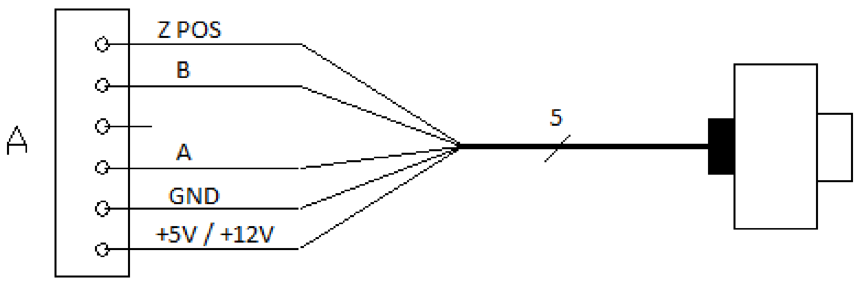
5.2.4 Connection of an encoder

ACE0/COMBIAC0 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.

A25	+5V/+12V	Positive power supply.
A5	GND	Negative power supply.
A14	ENC A	Phase A.
A13	ENC B	Phase B.
A20	Z POS	Z-index.



Connection of a standard encoder.



Connection of an encoder with zero-position signal.

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 pulses/rev can be properly set using the dedicated parameters (see paragraph 8.2.5).

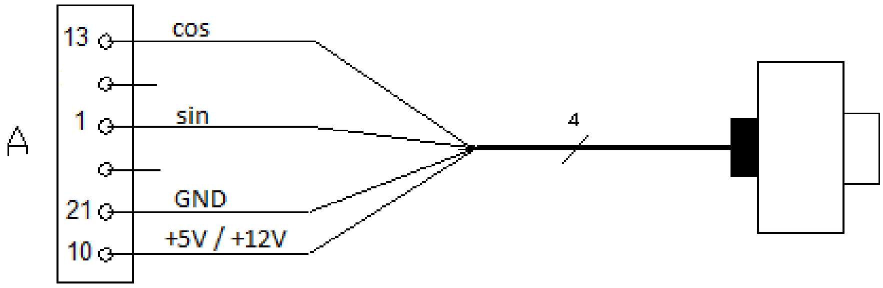
The maximum speed detectable by standard hardware configuration can be limited depending on number of pulse/rev. Contact Zapi technician for checking this aspect.

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.

5.2.5 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.

A25	+5V/+12V	Positive power supply.
A5	GND	Negative power supply.
A18	SIN	Sine signal.
A21	COS	Cosine signal.



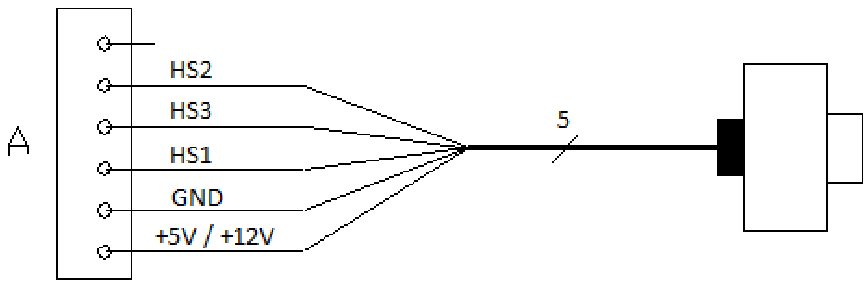
Connections of a sin/cos sensor.

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.

5.2.6 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.

A25	+5V/+12V	Positive power supply.
A5	GND	Negative power supply.
A13	HS1	Hall sensor 1.
A14	HS2	Hall sensor 2.
A18	HS3	Hall sensor 3.

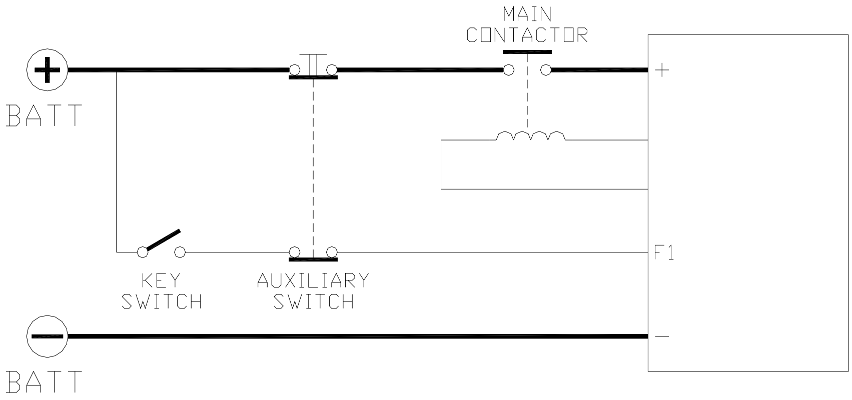


Connection of Hall sensors.

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.

5.2.7 Connection of main contactor and key switch

- Main contactor and key switch can be connected 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.

5.2.8 Insulation of the 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 or malfunctions of the device itself.
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 overtakes the speed set-point.
- The system can perform an electrical stop on a ramp (the machine is electrically held in place) for a programmable time (see also paragraph 8.2.1).
- 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 can drive an electromechanical brake.
- Hydraulic steering function:
  - When ACE0/COMBIAC0 works as traction inverter:
    - The traction inverter sends a "hydraulic steering function" request to the pump inverter on the CAN bus line.
    - If the pump inverter is not present (for ex: tractor application), the traction inverter can manage a hydraulic steering function by driving a hydraulic DC steering motor with DC section (see also paragraph 8.2.1 – HYDRO SETTINGS).
  - When ACE0/COMBIAC0 works as pump inverter:
    - The pump inverter manage an "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.
- Self-diagnosis with faults that can be displayed through the console (Smart console, PC CAN Console) or Zapi MDI/Display.
- Modification of parameters through the programming console (Smart console, PC CAN Console).
- Internal hour-meter with values that can be displayed on the console.
- Memory of the last five alarms with relative hour-meter and temperature displayed on the console (Smart console, PC CAN Console).
- TESTER function within console (Smart console, PC CAN Console) for checking main parameters.

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 requested speed (determined by throttle position) and the actual speed of the vehicle.

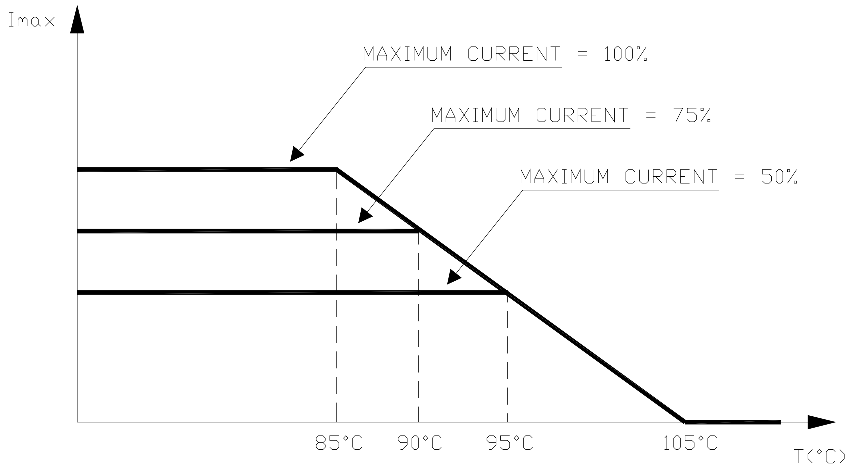
6.6 Protection and safety features

6.6.1 Protection features

ACE0 / COMBIAC0 is protected against the following failures 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 temperature excess. The temperature can never exceed

105 °C.



Thermal cutback

- **External agents**
  The inverter is protected against dust and liquid sprays to a degree of protection meeting IP65. Nevertheless, it is suggested to carefully study controller installation and position. With few simple shrewdness, the controller protection degree can be strongly increased.
- **Protection against uncontrolled movements**
  The main contactor will not close in the following conditions:
  - The power unit is not working.
  - The logic board does not work perfectly.
  - The output voltage of the accelerator is more than 1 V above the minimum value stored during the calibration procedure.
  - Travel-demand microswitches are active.
- **Low battery charge**
  When the battery charge is low, the maximum current is reduced to half of the maximum current programmed.
- **Protection against accidental start-up**
  A precise sequence of operations are necessary for the machine to start. Operation cannot begin if these operations are not carried out correctly. Requests for drive must be made after closing the key switch.

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.
<u>Machine manufacturer holds the responsibility for the truck safety features and related approval.</u>

7 START-UP HINTS

7.1 Check prior to initial power up

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

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

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

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

1. Verify that the proper motor controller for the application has been installed.
2. Verify that the battery voltage matches the motor controller nominal DC supply voltage showed on the product identification label.
3. Verify that the correct software for the application has been loaded.
4. Verify that all power 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 set-up procedure for ACE0/COMBIAC0 to be carried out 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 settings on different controllers, use the SAVE and RESTORE sequence. Remember to re-cycle the key switch if you want to make active any change to the configuration.

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

7.3.1 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 the magnetic-field zero position. Offset, amplitude and angle must be set before starting a PM for the first time.
Preliminary settings are the same as described above. Plus, an automatic acquisition procedure embedded in the inverter software is 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).
- The message ACQUIRING ABS indicates that the acquisition procedure is ready to start.

- Use the TESTER function to monitor the motor speed for the next 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 5 Hz), 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 sin/cos angle is acquired and stored.
- The next part is a sort of verification, where the 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.
- Re-cycle the key switch and verify that the 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, consider the following suggestions.
- 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 a 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 ACE0 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 the nominal

battery voltage (see paragraph 8.2.3).
- Check the wiring and that all commands are functioning. Use the TESTER function to have a real-time feedback about their state.
- Perform the accelerator acquisition using the PROGRAM VACC procedure (see paragraph 9.1).
- Set the maximum current for lift and lowering in MAX. CURRENT TRA and MAX. CURRENT BRK (see paragraph 8.2.1).
- Set the motor-related parameters. It is suggested to discuss them with Zapi technicians.
- Set parameter SET MOT.TEMPERAT according to the type of motor thermal sensor adopted.
- Set the acceleration delay (ACCEL MODULATION and 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 (see parameter HB ON / SR OFF in list SET OPTIONS).
- Set the other performance-related parameters such as MAX SPEED LIFT, 1ST SPEED COARSE, 2ND SPEED COARSE, 3RD SPEED COARSE.
- Set the parameters related to hydraulic steering, such as HYD SPEED FINE and HYDRO TIME.
- Test the pump in all operative conditions (with and without load, etc.).

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

8 PROGRAMMING & ADJUSTEMENTS

The ACE0/COMBIAC0 software is powerful and exhaustive, but it is also complex, with a long list of parameters that grant a fine control of all the 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 for modifying the parameters is the following.

- Before doing any change save a copy of the parameters set. This procedure is easy to do thanks to the Zapi Smart Console (see section 13.2.11) 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 it is necessary to use the Zapi console. Since the ACE0/COMBIAC0 has no external serial connector, three possibilities are available:

- To use the Zapi Smart Console connected to the CAN bus (ask directly to Zapi for the dedicated user manual).
- To use the PC CAN Console software. 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 is 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 of these tools.

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

8.1 Settings overview

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

PARAMETER CHANGE

- ACC. TORQUE DEL.
- DEC. TORQUE DEL.
- ACCELER. DELAY
- RELEASE BRAKING
- TILLER BRAKING
- INVERS. BRAKING
- DECEL. BRAKING
- PEDAL BRAKING
- SPEED LIMIT BRK.
- STEER BRAKING
- MAX SPEED FORW
- MAX SPEED BACK
- MAX SPEED LIFT
- 1ST PUMP SPEED
- 2ND PUMP SPEED
- 3RD PUMP SPEED
- 4TH PUMP SPEED
- 5TH PUMP SPEED
- HYD PUMP SPEED
- CUTBACK SPEED 1
- CUTBACK SPEED 2
- H&S CUTBACK
- CTB. STEER ALARM
- CURVE SPEED 1
- CURVE CUTBACK
- FREQUENCY CREEP
- TORQUE CREEP
- MAX. CURRENT TRA
- MAX. CURRENT BRK
- ACC SMOOTH
- INV SMOOTH
- STOP SMOOTH
- BRK SMOOTH
- STOP BRK SMOOTH
- BACKING SPEED
- BACKING TIME
- EB. ENGAGE DELAY
- AUXILIARY TIME
- ROLLING DW SPEED
- MIN EVP
- MAX EVP
- EVP OPEN DELAY
- EVP CLOSE DELAY
- MIN EVP2
- MAX EVP2
- EVP2 OPEN DELAY
- EVP2 CLOSE DELAY

SET OPTIONS

- HM DISPLAY OPT.
- HM CUSTOM 1 OPT.
- HM CUSTOM 2 OPT.
- TILL/SEAT SWITCH
- EB ON TILLER BRK
- BATTERY CHECK
- STOP ON RAMP
- PULL IN BRAKING
- SOFT LANDING
- QUICK INVERSION
- PEDAL BRK ANALOG
- HARD & SOFT
- HB ON / SR OFF
- MAIN POT. TYPE
- AUX POT. TYPE
- SET MOT.TEMPERAT
- STEERING TYPE
- M.C. FUNCTION
- EBRAKE ON APPL.
- AUX OUT FUNCTION
- SYNCRO
- AUTO PARK BRAKE
- AUTO LINE CONT.
- ACCEL MODULATION
- EVP TYPE
- EVP2 TYPE
- EV1
- EV2
- EV3
- EV4
- EV5
- HORN
- HIGH DYNAMIC
- INVERSION MODE
- STEER TABLE
- WHEELBASE MM
- FIXED AXLE MM
- STEERING AXLE MM
- REAR POT ON LEFT
- DISPLAY TYPE
- ABS.SENS.ACQUIRE

ADJUSTMENT

- SET BATTERY
- ADJUST KEY VOLT.
- ADJUST BATTERY
- SET POSITIVE PEB
- SET PBRK. MIN
- SET PBRK. MAX
- MIN LIFT DC
- MAX LIFT DC
- MIN LOWER
- MAX LOWER
- THROTTLE 0 ZONE
- THROTTLE X1 MAP
- THROTTLE Y1 MAP
- THROTTLE X2 MAP
- THROTTLE Y2 MAP
- THROTTLE X3 MAP
- THROTTLE Y3 MAP
- BAT. MIN ADJ.
- BAT. MAX ADJ.
- BDI ADJ STARTUP
- BDI RESET
- BATT.LOW TRESHLD
- STEER RIGHT VOLT
- STEER LEFT VOLT
- STEER ZERO VOLT
- MAX ANGLE RIGHT
- MAX ANGLE LEFT
- STEER DEAD ANGLE
- STEER ANGLE 1
- STEER ANGLE 2
- SPEED FACTOR
- SPEED ON MDI
- LOAD HM FROM MDI
- CHECK UP DONE
- CHECK UP TYPE
- MC VOLTAGE
- MC VOLTAGE RED.
- EB VOLTAGE
- EB VOLTAGE RED.
- PWM EV2
- PWM EV3
- MAX. MOTOR TEMP.
- STOP MOTOR TEMP.
- A.SENS.MAX SE
- A.SENS.MIN SE
- A.SENS.MAX CE
- A.SENS.MIN CE
- MAN.OFFSET ANGLE
- MAN.OFFS.ANG.DEC
- BAT.ENERGY SAVER
- MOT.T. T.CUTBACK
- VACC SETTING

SPECIAL ADJUSTMENT

- ADJUSTMENT #01
- ADJUSTMENT #02
- CURR. SENS. COMP
- DIS.CUR.FALLBACK
- SET CURRENT
- SET TEMPERATURE
- HW BATTERY RANGE
- DUTY PWM CTRAP
- PWM AT LOW FREQ
- PWM AT HIGH FREQ
- FREQ TO SWITCH
- DITHER AMPLITUDE
- DITHER FREQUENCY
- HIGH ADDRESS
- CAN BUS SPEED
- EXTENDED FORMAT
- DEBUG CANMESSAGE
- CONTROLLER TYPE
- SAFETY LEVEL
- RS232 CONSOLLE
- ID CANOPEN OFST
- 2ND SDO ID OFST
- VDC START UP LIM
- VDC UP LIMIT
- VDC START DW LIM
- VDC DW LIMIT
- RESOLVER PULSE

HARDWARE SETTING

- TOP MAX SPEED
- CONF.POSITIVE LC
- FEEDBACK SENSOR
- POSITIVE E.B.
- ROTATION CW ENC
- ROTATION CW MOT
- ROTATION CW POS
- ENCODER PULSES 1
- ENCODER PULSES 2
- MOTOR P. PAIRS 1
- MOTOR P. PAIRS 2
- . . .

HYDRO SETTING

- DC PUMP
- HYDRO PUMP SPEED
- HYDRO COMPENS.
- PUMP IMAX
- PU. ACCELER. DEL
- PU. DECELER. DEL
- MAX SPEED LIFTDC
- LIFT DC CUTBACK
- 1ST PU.DC SPEED
- 2ND PU.DC SPEED
- PU.DC CREEP SPD
- PU.DC COMPENSAT.
- HYDRO TIME
- HYDRO FUNCTION

8.2 Settings description

In the following paragraphs, parameters are presented as follows:

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

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

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 requests.

8.2.1 PARAMETER CHANGE

PARAMETER CHANGE		
Parameter	**Allowable range**	**Description**
ACC. TORQUE DEL. (T, TM, P, CO)	0.1 s ÷ 10 s (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. (T, TM, P, CO)	0.1 s ÷ 10 s (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 (T, TM, P, CO)	0.1 s ÷ 25.5 s (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. A special software feature manages the acceleration ramp depending on the speed setpoint (see paragraph 9.4).
RELEASE BRAKING (T, TM, P, CO)	0.1 s ÷ 25.5 s (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. A special software feature manages the deceleration ramp depending on the starting speed (see paragraph 9.5).

PARAMETER CHANGE		
Parameter	**Allowable range**	**Description**
TILLER BRAKING (T, TM)	0.1 s ÷ 25.5 s (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. A special software feature manages the deceleration ramp depending on the starting speed (see paragraph 9.5).
INVERS. BRAKING (T, TM, CO)	0.1 s ÷ 25.5 s (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. A special software feature manages the deceleration ramp depending on the starting speed (see paragraph 9.5).
DECEL. BRAKING (T, TM, P, CO)	0.1 s ÷ 25.5 s (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. A special software feature manages the deceleration ramp depending on the starting speed (see paragraph 9.5).
PEDAL BRAKING (T, TM, CO)	0.1 s ÷ 25.5 s (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. A special software feature manages the deceleration ramp depending on the starting speed (see paragraph 9.5).
SPEED LIMIT BRK. (T, TM)	0.1 s ÷ 25.5 s (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. A special software feature manages the deceleration ramp depending on the starting speed (see paragraph 9.5).
STEER BRAKING (T, TM)	0.1 s ÷ 25.5 s (steps of 0.1 s)	This parameter defines the deceleration ramp related to the steering angle, i.e. the time needed to decelerate the motor from 100 Hz down to 0 Hz. A special software feature manages the deceleration ramp depending on the starting speed (see paragraph 9.7).
MAX SPEED FORW (T, TM)	0% ÷ 100% (steps of 1%)	This parameter defines the maximum speed in forward direction as a percentage of TOP MAX SPEED.
MAX SPEED BACK (T, TM)	0% ÷ 100% (steps of 1%)	This parameter defines the maximum speed in backward direction as a percentage of TOP MAX SPEED.
MAX SPEED LIFT (P)	0% ÷ 100% (steps of 1%)	This parameter defines the maximum speed of the pump motor during lift, as a percentage of the maximum voltage applied to the pump motor.
1ST PUMP SPEED (P)	0% ÷ 100% (steps of 1%)	This parameter defines the speed of the pump motor when 1^{st} speed is requested. It represents a percentage of the maximum pump speed.
2ND PUMP SPEED (P)	0% ÷ 100% (steps of 1%)	This parameter defines the speed of the pump motor when 2^{nd} speed is requested. It represents a percentage of the maximum pump speed.

PARAMETER CHANGE		
Parameter	**Allowable range**	**Description**
3RD PUMP SPEED (P)	0% ÷ 100% (steps of 1%)	This parameter defines the speed of the pump motor when 3rd speed is requested. It represents a percentage of the maximum pump speed.
4TH PUMP SPEED (P)	0% ÷ 100% (steps of 1%)	This parameter defines the speed of the pump motor when 4th speed is requested. It represents a percentage of the maximum pump speed.
5TH PUMP SPEED (P)	0% ÷ 100% (steps of 1%)	This parameter defines the speed of the pump motor when 5th speed is requested. It represents a percentage of the maximum pump speed.
HYD PUMP SPEED (P)	0% ÷ 100% (steps of 1%)	This parameter defines the speed of the pump motor used for the steering, when HYDRO FUNCTION is ON. It represents a percentage of the maximum pump speed.
CUTBACK SPEED 1 (T, TM, P)	10% ÷ 100% (steps of 1%)	This parameter defines the maximum speed performed when cutback input 1 is active. It represents a percentage of TOP MAX SPEED.
CUTBACK SPEED 2 (T, TM, P)	10% ÷ 100% (steps of 1%)	This parameter defines the maximum speed performed when cutback input 2 is active. It represents a percentage of TOP MAX SPEED.
H&S CUTBACK (T, TM)	10% ÷ 100% (steps of 1%)	This parameter defines the maximum speed performed when the Hard-and-Soft function is active. It represents a percentage of TOP MAX SPEED.
CTB. STEER ALARM (T, TM)	0% ÷ 100% (steps of 1%)	This parameter defines the maximum traction speed 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 (T, TM)	0% ÷ 100% (steps of 1%)	This parameter defines the maximum traction speed when the steering angle is equal to the STEER ANGLE 1 angle. The parameter represents a percentage of TOP MAX SPEED.
CURVE CUTBACK (T, TM)	1% ÷ 100% (steps of 1%)	This parameter defines the maximum traction speed when the steering angle is equal to the STEER ANGLE 2 angle. The parameter represents a percentage of TOP MAX SPEED.
FREQUENCY CREEP (T, TM, P)	0.6 Hz ÷ 25 Hz (steps of 0.1 Hz)	This parameter defines the minimum speed when the forward- or reverse-request switch is closed, but the accelerator is at its minimum.
TORQUE CREEP (T, TM, P, CO)	0% ÷ 100% (steps of 1/255)	This parameter defines the minimum torque applied when torque control is enabled and the forward- or reverse-request switch is closed, but the accelerator is at its minimum.
MAX. CURRENT TRA (T, TM, P, CO)	0% ÷ 100% (steps of 1%)	This parameter defines the maximum current applied to the motor during acceleration, as a percentage of the factory-calibrated maximum current.
MAX. CURRENT BRK (T, TM, P, CO)	0% ÷ 100% (steps of 1%)	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 (T, TM, P, CO)	1 ÷ 5 (steps of 0.1)	This parameter defines the acceleration profile: 1 results in a linear ramp, higher values result in smoother parabolic profiles.
INV SMOOTH (T, TM, CO)	1 ÷ 5 (steps of 0.1)	This parameter defines the acceleration profile performed when the truck changes direction: 1 results in a linear ramp, higher values result in smoother parabolic profiles.
STOP SMOOTH (T, TM, P, CO)	3 Hz ÷ 100 Hz (steps of 1 Hz)	This parameter defines the frequency at which the smoothing effect of the acceleration profile ends.
BRK SMOOTH (T, TM, CO)	1 ÷ 5 (steps of 0.1)	This parameter defines the deceleration profile: 1 results in a linear ramp, higher values result in smoother parabolic profiles.
STOP BRK SMOOTH (T, TM, CO)	3 Hz ÷ 100 Hz (steps of 1 Hz)	This parameter defines the frequency at which the smoothing effect of the deceleration profile ends.
BACKING SPEED (T, TM)	0% ÷ 100% (steps of 1%)	This parameter defines maximum speed performed when the inching function is active. The parameter represents a percentage of TOP MAX SPEED.
BACKING TIME (T, TM)	0 s ÷ 10 s (steps of 0.1 s)	This parameter defines the duration of the inching function.
EB. ENGAGE DELAY (T, TM, P, CO)	0 s ÷ 12.75 s (steps of 0.05 s)	This parameter defines the delay introduced between the traction request and the actual activation of the traction motor. This takes into account the delay occurring between the activation of the EB output (i.e. after a traction request) and the effective EB release, so to keep the motor stationary until the electromechanical brake is actually released. The releasing delay of the brake can be measured or it can be found in the datasheet.
AUXILIARY TIME (T, TM, P, CO)	0 s ÷ 10 s (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 (T, TM, P, CO)	1 Hz ÷ 50 Hz (steps of 1 Hz)	This parameter defines the maximum speed for the rolling-down function.
MIN EVP (A)	0% ÷ 100% (steps of 1/255)	This parameter determines the minimum current applied to the EVP when the potentiometer position is at the minimum. This parameter is not effective if the EVP is programmed like an on/off valve.
MAX EVP (A)	0% ÷ 100% (steps of 1/255)	This parameter determines the maximum current applied to the EVP when the potentiometer position is at the maximum. This parameter also determines the current value when the EVP is programmed like an ON/OFF valve.
EVP OPEN DELAY (A)	0 s ÷ 12.75 s (steps of 0.05 s)	It determines the current increase rate on EVP. The parameter sets the time needed to increase the current to the maximum possible value.

PARAMETER CHANGE		
Parameter	**Allowable range**	**Description**
EVP CLOSE DELAY (A)	0 s ÷ 12.75 s (steps of 0.05 s)	It determines the current decrease rate on EVP. The parameter sets the time needed to decrease the current from the maximum possible value to zero.
MIN EVP2 (A)	0% ÷ 100% (steps of 1/255)	This parameter determines the minimum current applied on the EVP2 when the position of the potentiometer is at the minimum. This parameter is not effective if the EVP2 is programmed like an on/off valve.
MAX EVP2 (A)	0% ÷ 100% (steps of 1/255)	This parameter determines the maximum current applied to the EVP2 when the position of the potentiometer is at the maximum. This parameter also determines the current value when the EVP2 is programmed like an ON/OFF valve.
EVP2 OPEN DELAY (A)	0 s ÷ 12.75 s (steps of 0.05 s)	It determines the acceleration ramp on EVP2. The parameter sets the time needed to increase the current to the maximum possible value.
EVP2 CLOSE DELAY (A)	0 s ÷ 12.75 s (steps of 0.05 s)	It determines the deceleration ramp on EVP2. The parameter sets the time needed to decrease the current from the maximum possible value to zero.

HYDRO SETTINGS

COMBIAC0 has the possibility to drive an AC motor and a DC pump motor simultaneously, the PARAMETER CHANGE list has these additional parameters relative to the DC pump control.

HYDRO SETTINGS		
Parameter	**Allowable range**	**Description**
DC PUMP (A)	OFF ÷ ON	It manages the DC chopper: **OFF =** Only AC three-phase traction controller (ACE0). **ON =** AC three-phase traction controller and DC pump chopper (COMBIAC0).
HYDRO PUMP SPEED (A)	0% ÷ 100% (steps of 1)	It defines the maximum speed of the hydraulic pump. In particular, it defines the voltage applied to the pump motor as a percentage of the maximum voltage.
HYDRO COMPENS. (A)	0% ÷ 100% (steps of 1%)	This parameter defines the voltage compensation applied to the motor when the hydraulic pump is active. The amount of compensation is a function of the motor current. Aim of this function is to keep the speed constant in different operating conditions.
PUMP IMAX (A)	0% ÷ 100% (steps of 1%)	It defines the maximum current of the DC pump chopper.
PU. ACCELER. DEL (A)	0.1 s ÷ 25.5 s (steps of 0.1 s)	It defines the acceleration ramp for the pump motor.

HYDRO SETTINGS		
Parameter	**Allowable range**	**Description**
PU. DECELER. DEL (A)	0.1 s ÷ 25.5 s (steps of 0.1 s)	It defines the deceleration ramp for the pump motor.
MAX SPEED LIFTDC (A)	0% ÷ 100% (steps of 1%)	It limits the maximum speed of the lifting function. In particular, it defines the voltage applied to the pump motor as a percentage of the maximum voltage.
LIFT DC CUTBACK (A)	0% ÷ 100% (steps of 1%)	It limits the maximum speed of the lifting cutback function. In particular, it defines the voltage applied to the pump motor as a percentage of the maximum voltage.
1ST PU.DC SPEED (A)	0% ÷ 100% (steps of 1%)	It limits the maximum speed of the 1st function. In particular, it defines the voltage applied to the pump motor as a percentage of the maximum voltage.
2ND PU.DC SPEED (A)	0% ÷ 100% (steps of 1%)	It limits the maximum speed of the 2nd function. In particular, it defines the voltage applied to the pump motor as a percentage of the maximum voltage.
PU.DC CREEP SPD (A)	0% ÷ 100% (steps of 1%)	It sets the minimum speed for the pump motor. In particular, it defines the voltage applied to the pump motor when the Lift SW is closed, as a percentage of the maximum voltage.
PU.DC COMPENSAT. (A)	0% ÷ 100% (steps of 1%)	This parameter defines the voltage compensation applied to the motor when the proportional lifting function is active. The amount of compensation is a function of the motor current. Aim of this function is to reduce, as far as possible, the speed difference between the loaded and unloaded conditions.
HYDRO TIME (A)	0 s ÷ 20 s (steps of 0.1 s)	(T, TM, TS, CO): in traction configurations, it defines the time period in that the DC pump motor is left on after the travel demand has been released. (P): in pump configuration, it specifies how much time the AC motor must remain active after the hydraulic request has been released.
HYDRO FUNCTION (A)	NONE ÷ OPTION #2	This parameter selects how the pump that enables hydraulic functions is managed. **NONE =** No hydraulic functions is present. **KEYON =** ACE0/COMBIAC0 drives a pump motor from key-on and constantly keeps it on. **RUNNING =** ACE0/COMBIAC0 drives a pump motor only when there is an associated request (for example a lift request). **OPTION #1 =** ACE0/COMBIAC0 does not control a pump motor, but the truck integrates hydraulic functions and the ACE0/COMBIAC0 is the master controller, controlling them through a valve. So the output that drives the hydraulic valve (for example EVP) is activated at key-on. **OPTION #2 =** Same as OPTION#1, but the valve is driven only when there is the associated request.

8.2.2 SET OPTIONS

SET OPTIONS		
Parameter	**Allowable range**	**Description**
HM DISPLAY OPT. (T, TM, P, CO)	0 ÷ 6	This parameter defines the configuration for the hour meter shown on a display (i.e. MDI). The possible settings are the same described for parameter HM CUSTOM 1 OPT..
HM CUSTOM 1 OPT. (T, TM, P, CO)	0 ÷ 6	This parameter decides the configuration for the hour meter number 1 accessible to the customer. The possible settings are: **0:** The hour meter counts since the controller is on. **1:** The hour meter counts when the three-phase power bridge is active. **2:** The hour meter counts when the DC motor power bridge is active. **3:** The hour meter counts when one of the valve outputs is active. **4:** The hour meter counts when the three-phase power bridge is active or the DC motor power bridge is active. **5:** The hour meter counts when the DC motor power bridge is active or one of the valve outputs is active. **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.
HM CUSTOM 2 OPT. (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 (T, TM, P)	HANDLE ÷ SEAT	This option handles the input A1. This input opens when the operator leaves the truck. It is connected to a key voltage when the operator is present. **HANDLE =** A1 is managed as tiller input (no delay when released). **DEADMAN =** A1 is managed as dead-man input (no delay when released). **SEAT =** A1 is managed as seat input (with a delay when released and the de-bouncing function).
EB ON TILLER BRK (T)	OFF ÷ ON	This option defines how the electromechanical brake is managed depending on the status of tiller/seat input: **ON =** the electromechanical brake is engaged as soon as the tiller input goes into OFF state. The deceleration ramp defined by TILLER BRAKING parameter has no effect. **OFF =** when the tiller input goes into OFF state, the “tiller braking” ramp is applied before engaging the electromechanical brake.

SET OPTIONS		
Parameter	**Allowable range**	**Description**
BATTERY CHECK (T, TM, P, CO)	0 ÷ 3	This option specifies the management of the low battery charge situation. There are four levels of intervention: **0 =** The battery charge level is evaluated but ignored, meaning that no action is taken when the battery runs out. **1 =** The BATTERY LOW alarm occurs when the battery level is evaluated to be lower or equal to BATT.LOW TRESHLD. With the BATTERY LOW alarm, the control reduces the maximum speed down to 24% of the full speed and it also reduces the maximum current down to 50% of the full current. **2 =** The BATTERY LOW alarm occurs when the battery level is evaluated to be lower or equal to BATT.LOW TRESHLD. **3 =** The BATTERY LOW alarm occurs when the battery level is evaluated to be lower or equal to BATT.LOW TRESHLD. With the BATTERY LOW alarm, the control reduces the maximum speed down to 24% of the full speed. See parameter BATT.LOW TRESHLD in the ADJUSTMENTS list, paragraph 8.2.3.
STOP ON RAMP (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). **ON =** The stop-on-ramp feature is performed for a time set in the AUXILIARY TIME parameter. **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. 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 (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. **ON =** When the operator releases the traction request, the inverter keeps running the truck, as to oppose the friction that tends to stop it. Similarly, in pump applications, when the operator releases the lift request, the inverter keeps running the pump avoiding the unwanted descent of the forks. **OFF =** When the operator releases the traction (or lift) request, the inverter does not power anymore the motor. This setting is useful especially for traction application. When the truck is travelling over a ramp and the driver wants to stop it by gravity, the motor must not be powered anymore, until the truck stops.

SET OPTIONS		
Parameter	**Allowable range**	**Description**
SOFT LANDING (A)	OFF ÷ ON	This parameter enables or disables the control of the deceleration rate of the truck when the accelerator is released. **ON =** When the accelerator is released, the inverter controls the deceleration rate of the truck through the application of a linearly decreasing torque curve. This is useful when the operator releases the accelerator while the truck is going uphill. If the rise is steep, the truck may stop fast and may also go backwards in short time, possibly leading to a dangerous situation. **OFF =** When the accelerator is released, the inverter does not control the deceleration rate of the truck, instead it stops driving the motor.
QUICK INVERSION (T, TM, P)	NONE ÷ BELLY	This parameter defines the quick-inversion functionality. **NONE =** The quick-inversion function is not managed. **BRAKE =** Upon a quick-inversion request, the motor is braked. **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). **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 (T, TM)	OFF ÷ ON	This parameter defines the kind of brake pedal adopted. **ON =** Brake pedal outputs an analog signal, braking is linear. **OFF =** Brake pedal outputs a digital signal, braking is on/off.
HARD & SOFT (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. **ON =** H&S function is enabled. **OFF =** H&S function is disabled (default option).
HB ON / SR OFF (T, TM)	OFF, ON	This parameter defines the function associated with input A18. **ON =** Handbrake. **OFF =** Speed reduction.

<table>
<tr><th colspan="3">SET OPTIONS</th></tr>
<tr><th>Parameter</th><th>Allowable range</th><th>Description</th></tr>
<tr>
<td>MAIN POT. TYPE
(T, TM)</td>
<td>0 ÷ 11</td>
<td>This parameter decides the feature of the main potentiometer, connected to pin A15.
<table>
<tr><th>#</th><th>Pot. type</th><th>Low to High / High to Low</th><th>Direction switches</th><th>Enable switch</th><th>En. dead band</th></tr>
<tr><td>0</td><td>V-type</td><td>L to H</td><td>X</td><td></td><td></td></tr>
<tr><td>1</td><td>V-type</td><td>L to H</td><td>X</td><td></td><td>X</td></tr>
<tr><td>2</td><td>V-type</td><td>H to L</td><td>X</td><td></td><td></td></tr>
<tr><td>3</td><td>V-type</td><td>H to L</td><td>X</td><td></td><td>X</td></tr>
<tr><td>4</td><td>Z-type</td><td>L to H</td><td>X</td><td></td><td></td></tr>
<tr><td>5</td><td>Z-type</td><td>L to H</td><td>X</td><td></td><td>X</td></tr>
<tr><td>6</td><td>Z-type</td><td>L to H</td><td></td><td>X</td><td>X</td></tr>
<tr><td>7</td><td>Z-type</td><td>L to H</td><td></td><td></td><td>X</td></tr>
<tr><td>8</td><td>Z-type</td><td>H to L</td><td>X</td><td></td><td></td></tr>
<tr><td>9</td><td>Z-type</td><td>H to L</td><td>X</td><td></td><td>X</td></tr>
<tr><td>10</td><td>Z-type</td><td>H to L</td><td></td><td>X</td><td>X</td></tr>
<tr><td>11</td><td>Z-type</td><td>H to L</td><td></td><td></td><td>X</td></tr>
</table>
</td>
</tr>
<tr>
<td>AUX POT. TYPE
(T, TM, P)</td>
<td>0 ÷ 12</td>
<td>This parameter decides the type of the auxiliary potentiometer, connected to pin A30.
<table>
<tr><th>#</th><th>Pot. type</th><th>Low to High / High to Low</th><th>Direction switches</th><th>Enable switch</th><th>En. dead band</th></tr>
<tr><td>0 ÷ 11</td><td colspan="5">Same as MAIN POT. TYPE, see previous parameter.</td></tr>
<tr><td>12</td><td>No</td><td>H to L</td><td>X</td><td>X</td><td></td></tr>
<tr><td>13 ÷ 15</td><td>For future uses</td><td>13 ÷ 15</td><td>For future uses</td><td>13 ÷ 15</td><td>For future uses</td></tr>
</table>
</td>
</tr>
<tr>
<td>SET MOT.TEMPERAT
(T, TM, P, CO)</td>
<td>NONE ÷ OPTION#2</td>
<td>Sets the motor temperature sensor type.
NONE = no motor thermal sensor switch is connected.
DIGITAL = a digital (ON/OFF) motor thermal sensor is connected to A22.
OPTION#1 = an analogue motor thermal sensor is connected to A22. The temperature sensor is a KTY 84-130 PTC (positive thermal coefficient resistance).
OPTION#2 = an analogue motor thermal sensor is connected to A22. The temperature sensor is a KTY 83-130 PTC (positive thermal coefficient resistance)
OPTION#3 = an analog motor thermal sensor is connected to A22. The temperature sensor is a PT1000 PTC (positive thermal coefficient resistance).</td>
</tr>
</table>

SET OPTIONS		
Parameter	**Allowable range**	**Description**
STEERING TYPE (T, TM)	NONE ÷ ANALOG	It allows to select which type of steering unit is connected to the controller. **NONE =** NO steering module is present on the truck, ACE0/COMBIAC0 does not wait for CAN message by the EPS and it does not apply EPS and braking steer cutback. **OPTION#1 =** EPS is present and it is configured with an ENCODER + TOGGLE SWITCHES. These signals are transmitted to ACE0/COMBIAC0 over CAN bus. **OPTION#2 =** EPS is present and it is configured with a POT + ENCODER. These signals are transmitted to ACE0/COMBIAC0 over CAN bus. **ANALOG =** A hydraulic steer is used on the truck and ACE0/COMBIAC0 is reading through one of its analog input the signal coming from a wheel potentiometer in order to read the wheel rotation.
M.C. FUNCTION (A)	OFF ÷ OPTION#2	This parameter defines the configuration of the NLC output (A12), dedicated to the main – or line – contactor. **OFF =** Main contactor is not present. Diagnoses are masked and MC is not driven. **ON =** Main contactor is in standalone configuration. Diagnoses are performed and MC is closed after key-on only if they have passed. **OPTION#1 =** For a traction-and-pump setup, with only one main contactor for both controllers. Diagnoses are performed and MC is closed after key-on only if they have passed. **OPTION#2 =** For a traction-and-pump setup, with two main contactors. Each controller drives its own MC. Diagnoses are performed and MCs are closed after key-on only if they have passed.
M.C. OUTPUT (T, TM, P, CO)	ABSENT, PRESENT	This parameter defines whether a load coil is connected to the NLC output (A12) or not. **ABSENT =** NLC output is not connected to any load coil. **PRESENT =** NLC output is connected to a load coil (by default, that of the main contactor).
EBRAKE ON APPL. (T, 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 (A)	NONE, BRAKE	This parameter enables or disables the NEB output (A4), dedicated to the electromechanical brake. **NONE =** Diagnoses are masked and E.B. is not driven upon a traction request. **BRAKE =** E.B. is driven upon a traction request if all the related diagnoses pass. The behavior on a slope depends on the STOP ON RAMP setting. **Do not use this setting if the electromechanical brake is not really present.** **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 (CO)	OFF ÷ ON	This parameter enables or disables the syncro message. **OFF =** The syncro message is not used. **ON =** The syncro message is enabled.
AUTO PARK BRAKE (CO)	OFF ÷ ON	This parameter enables or disables the autonomous management of the brake. **OFF =** E.B. is activated or deactivated according to the signal received via CAN bus. **ON =** E.B. is managed by the controller itself ignoring any activation/deactivation signal received via CAN bus.
AUTO LINE CONT. (CO)	OFF ÷ ON	This parameter enables or disables the autonomous management of the main contactor. **OFF =** Main contactor is opened or closed according to the signals received by CAN bus. **ON =** Main contactor is managed by the controller itself ignoring any activation/deactivation signal received via CAN bus.
ACCEL MODULATION (T, TM, P, CO)	OFF ÷ ON	This parameter enables or disables the acceleration-modulation function. **OFF =** The acceleration rate is inversely proportional to the ACCEL DELAY parameter. **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. See paragraph 9.4.
EVP TYPE (A)	NONE ÷ DIGITAL	This parameter defines the behavior of output EVP1 (A24). **NONE =** Output A24 is not enabled. **ANALOG =** Output A24 manages a PWM-modulated current-controlled proportional valve. **DIGITAL =** Output A24 manages an on/off valve.

SET OPTIONS		
Parameter	**Allowable range**	**Description**
EVP2 TYPE (A)	NONE ÷ DIGITAL	This parameter defines the behavior of output EVP2 (A23). **NONE =** Output A23 is not enabled. **ANALOG =** Output A23 manages a PWM current-controlled proportional valve. **DIGITAL =** Output A23 manages an on/off valve.
EV1 (A)	ABSENT ÷ OPTION#2	This parameter defines the behavior of output EV1 (A9). **ABSENT =** Output A9 is not enabled. **OPTION#1 =** Output A9 manages an ON/OFF valve. By default it is activated by the 1st speed command. **OPTION#2 =** free for future use.
EV2 (A)	ABSENT ÷ DIGITAL	This parameter defines the behavior of output EV2 (A11). **ABSENT =** Output A11 is not enabled. **DIGITAL =** Output A11 manages a PWM voltage-controlled valve. The PWM frequency is 1 kHz and the duty cycle depends on parameter PWM EV2 (ADJUSTMENTS list, paragraph 8.2.3).
EV3 (A)	ABSENT ÷ DIGITAL	This parameter defines the behavior of output EV3 (A33). **ABSENT =** Output A33 is not enabled. **DIGITAL =** Output A33 manages a PWM voltage-controlled valve. The PWM frequency is 1 kHz and the duty cycle depends on parameter PWM EV3 (ADJUSTMENTS list, paragraph 8.2.3).
EV4 (A)	ABSENT ÷ DIGITAL	This parameter defines the behavior of output EV4 (A34). **ABSENT =** Output A34 is not enabled. **DIGITAL =** Output A34 manages an on/off valve.
EV5 (A)	ABSENT ÷ DIGITAL	This parameter defines the behavior of output EV5 (A8). **ABSENT =** Output A8 is not enabled. **DIGITAL =** Output A8 manages an on/off valve.
HORN (A)	ABSENT ÷ DIGITAL	It enables the control of output HORN (A26). **ABSENT =** Output A26 is not enabled. **DIGITAL =** Output A26 manages an ON/OFF valve.
HIGH DYNAMIC (T, TM, P, CO)	OFF ÷ ON	This parameter enables or disables the high-dynamic function. **ON =** All acceleration and deceleration profiles set by dedicated parameters are ignored and the controller works always with maximum performance. **OFF =** Standard behavior.

SET OPTIONS		
Parameter	**Allowable range**	**Description**
INVERSION MODE (T, TM)	OFF ÷ ON	This parameter sets the behavior of the Quick-Inversion input (A7): **ON =** The Quick-Inversion switch is normally closed (function is active when the switch is open). **OFF =** The Quick-Inversion switch is normally open (function is active when the switch is closed).
STEER TABLE (TM)	NONE ÷ OPTION#2	This parameter defines the steering table. **NONE =** The inverter does not follow any predefined steering table, but it creates a custom table according to parameters WHEELBASE MM, FIXED AXLE MM, STEERING AXLE MM and REAR POT ON LEFT. **OPTION#1 =** Three-wheels predefined steering table. **OPTION#2 =** Four-wheels predefined steering table. The steering table depends on the truck geometry. The two options available as default may not fit the requirements of your truck. It is advisable to define the geometrical dimensions of the truck in the parameters listed below in order to create a custom table. It is strongly recommended to consult paragraph 9.13 in order to properly understand how to fill the following parameters. If the steering performance of the truck do not match your requirements even if you have defined the right truck geometry, contact a Zapi technician in order to establish if a custom steering table has to be created.
WHEELBASE MM (TM)	0 ÷ 32000	This parameter must be filled with the wheelbase distance, i.e. the distance present between the two truck’s axles. The distance must be expressed in millimeters. See paragraph 9.13.
FIXED AXLE MM (TM)	0 ÷ 32000	This parameter must be filled with the axle length at which the non-steering wheels are connected. The length must be expressed in millimeters. See paragraph 9.13.
STEERING AXLE MM (TM)	0 ÷ 32000	This parameter must be filled with the axle length at which the non-steering wheels are connected. The length must be expressed in millimeters. See paragraph 9.13.
REAR POT ON LEFT (TM)	OFF ÷ ON	This parameter defines the position of the steering potentiometer. **OFF =** The steering potentiometer is not placed on the rear-left wheel. **ON =** The steering potentiometer is placed on the rear-left wheel.

SET OPTIONS		
Parameter	**Allowable range**	**Description**
DISPLAY TYPE (T, TM, P)	0 ÷ 9	This parameter defines which type of display is connected to the inverter. **0 =** None. **1 =** MDI PRC. **2 =** ECO DISPLAY. **3 =** SMART DISPLAY. **4 =** MDI CAN. **5 ÷ 9 =** available for future developments.
ABS.SENS.ACQUIRE (Only for BLE0 with sin/cos or PWM sens) (A)	OFF ÷ ON	This parameter activates the acquisition of motor speed sensor used for PMSM (Permanent-Magnets Synchronous Motor). **Contact Zapi technicians for a detailed description of the acquisition procedure.**

IMPORTANT NOTE*: output EV5 may be not available depending on hardware configuration even if the parameter EV5 is set as PRESENT.*

8.2.3 ADJUSTMENTS

ADJUSTMENTS		
Parameter	**Allowable range**	**Description**
SET BATTERY (A)	24 V ÷ 80 V	This parameter must be set to the nominal battery voltage. The available options are: **24V, 36V, 48V, 72V, 80V**
ADJUST KEY VOLT. (A)		Fine adjustment of the key voltage measured by the controller. Calibrated by Zapi production department during the end of line test.
ADJUST BATTERY (A)		Fine adjustment of the battery voltage measured by the controller. Calibrated by Zapi production department during the end of line test.
SET POSITIVE PEB (A)	12 V ÷ 80 V	This parameter defines the supply-voltage feeding pin A3. The available values are: **12V, 24V, 36V, 40V, 48V, 72V, 80V**
SET PBRK. MIN (T, TM, CO)	0 V ÷ 25.5 V (steps of 0.1V)	It records the minimum value of brake potentiometer when the brake is analog.
SET PBRK. MAX (T, TM, CO)	0 V ÷ 25.5 V (steps of 0.1V)	It records the maximum value of brake potentiometer when the brake is analog.

ADJUSTMENTS		
Parameter	**Allowable range**	**Description**
MIN LIFT DC **(Read Only)** (T, TM, TS, P)	0 V ÷ 25.5 V (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)	0 V ÷ 25.5 V (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)	0 V ÷ 25.5 V (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)	0 V ÷ 25.5 V (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% (steps of 1%)	This parameter defines a dead band in the accelerator input curve. See paragraph 9.8.
THROTTLE X1 MAP (T, TM, P)	0% ÷ 100% (steps of 1%)	This parameter defines the accelerator input curve. See paragraph 9.8.
THROTTLE Y1 MAP (T, TM, P)	0% ÷ 100% (steps of 1%)	This parameter defines the accelerator input curve. See paragraph 9.8.
THROTTLE X2 MAP (T, TM, P)	0% ÷ 100% (steps of 1%)	This parameter defines the accelerator input curve. See paragraph 9.8.
THROTTLE Y2 MAP (T, TM, P)	0% ÷ 100% (steps of 1%)	This parameter defines the accelerator input curve. See paragraph 9.8.
THROTTLE X3 MAP (T, TM, P)	0% ÷ 100% (steps of 1%)	This parameter defines the accelerator input curve. See paragraph 9.8.
THROTTLE Y3 MAP (T, TM, P)	0% ÷ 100% (steps of 1%)	This parameter defines the accelerator input curve. See paragraph 9.8.
BAT. MIN ADJ. (T, TM, P, CO)	-12.8% ÷ 12.7% (steps of 0.1%)	It adjusts the lower level of the battery discharge table. It is used to calibrate the discharge algorithm for the battery used. See paragraph 9.10.
BAT. MAX ADJ. (T, TM, P, CO)	-12.8% ÷ 12.7% (steps of 0.1%)	It adjusts the upper level of the battery discharge table. It is used to calibrate the discharge algorithm for the battery used. See paragraph 9.10.

ADJUSTMENTS		
Parameter	**Allowable range**	**Description**
BDI ADJ STARTUP (T, TM, P, CO)	-12.8% ÷ 12.7% (steps of 0.1%)	Adjusts the level of the battery charge table at start-up, in order to calculate the battery charge at key-on. See paragraph 9.10.
BDI RESET (T, TM, P, CO)	0% ÷ 100% (steps of 1%)	It adjusts the minimum variation of the battery discharge table to update the battery % at the start up. It is used to calibrate the discharge algorithm for the battery used. See paragraph 9.10.
BATT.LOW TRESHLD (T, TM, P, CO)	1% ÷ 50% (steps of 1%)	This parameter defines the minimum charge percentage below which the BATTERY LOW alarm rises.
STEER RIGHT VOLT (T,TM)	0 V ÷ 25.5 V (steps of 0.1 V)	This parameter records the maximum steering-control voltage while turning right. See paragraph 9.3.
STEER LEFT VOLT (T,TM)	0 V ÷ 25.5 V (steps of 0.1 V)	This parameter records the maximum steering-control voltage while turning left. See paragraph 9.3.
STEER ZERO VOLT (T,TM)	0 V ÷ 25.5 V (steps of 0.1 V)	This parameter records the maximum steering-control voltage when it is in the straight-ahead position. See paragraph 9.3.
MAX ANGLE RIGHT (T,TM)	0° ÷ 90° (steps of 1°)	This parameter defines the maximum steering-wheel angle while turning right.
MAX ANGLE LEFT (T,TM)	0° ÷ 90° (steps of 1°)	This parameter defines the maximum steering-wheel angle while turning left.
STEER DEAD ANGLE (T, TM)	1° ÷ 50° (steps of 1°)	This parameter defines the maximum steering-wheel angle up to which the permitted traction speed is 100%. See paragraph 9.7.
STEER ANGLE 1 (T, TM)	1° ÷ 90° (steps of 1°)	This parameter defines the steering-wheel angle at which traction speed is reduced to the value imposed by CURVE SPEED 1. For steering-wheel angles between STEER DEAD ANGLE and STEER ANGLE 1, traction speed is reduced linearly from 100% to CURVE SPEED 1. See paragraph 9.7.
STEER ANGLE 2 (T, TM)	1° ÷ 90° (steps of 1°)	This parameter defines the steering-wheel angle beyond which traction speed is reduced to CURVE CUTBACK. For steering-wheel angles between STEER ANGLE1 and STEER ANGLE 2 traction speed is reduced linearly from CURVE SPEED 1 to CURVE CUTBACK. See paragraph 9.7.

ADJUSTMENTS		
Parameter	**Allowable range**	**Description**
SPEED FACTOR (T, TM, CO)	0 ÷ 255 (steps of 1)	This parameter defines the coefficient used for evaluating the truck speed (in km/h) from the motor frequency (in Hz), according to the following formula: $Speed\ [km/h] = 10 \cdot \frac{frequency\ [Hz]}{Speed\ factor}$
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.
CHECK UP TYPE (T, TM, P, CO)	NONE ÷ OPTION#3	This parameter defines the CHECK UP NEEDED warning: **NONE =** no CHECK UP NEEDED warning. **OPTION#1 =** CHECK UP NEEDED warning shown on the hand-set and MDI after 300 hours. **OPTION#2 =** Like OPTION#1, plus speed reduction intervenes after 340 hours. **OPTION#3 =** Like OPTION#2, plus the truck definitively stops after 380 hours.
MC VOLTAGE (A)	0% ÷ 100% (steps of 1%)	This parameter specifies the duty-cycle (t_{ON}/T_{PWM}) of the PWM applied to the main-contactor output (A12) during the first second after the activation signal that causes the main contactor to close.
MC VOLTAGE RED. (A)	0% ÷ 100% (steps of 1%)	This parameter defines a percentage of MC VOLTAGE parameter and it determines the duty-cycle applied after the first second of activation of the contactor. For details and examples see paragraph 9.9.
EB VOLTAGE (A)	0% ÷ 100% (steps of 1%)	This parameter specifies the duty-cycle (t_{ON}/T_{PWM}) of the PWM applied to the electromechanical brake output (A4) during the first second after the activation signal that causes the electromechanical brake to release.
EB VOLTAGE RED. (A)	0% ÷ 100% (steps of 1%)	This parameter defines a percentage of EB VOLTAGE parameter and it determines the duty-cycle applied after the first second since when the electromechanical brake is released. For details and examples see paragraph 9.9.

ADJUSTMENTS		
Parameter	**Allowable range**	**Description**
PWM EV2 (A)	0% ÷ 100% (255 steps)	This parameter defines the duty-cycle of the PWM applied to EV2 output (A11).
PWM EV3 (A)	0% ÷ 100% (255 steps)	This parameter defines the duty-cycle of the PWM applied to EV3 output (A33).
MAX. MOTOR TEMP. (T, TM, P, CO)	60°C ÷ 175°C (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. (T, TM, P, CO)	60°C ÷ 190°C (steps of 1°C)	This parameter defines the maximum motor temperature permitted, above which the controller stops driving the motor.
A.SENS.MAX SE (Only for BLE0 with sin/cos sensor) (A)	Volt	This parameter records the maximum offset voltage at the sine analog input during the auto-teaching procedure. It can be compared with the A.SENS.OFFSET SR entry value.
A.SENS.MIN SE (Only for BLE0 with sin/cos sensor) (A)	Volt	This parameter records the minimum offset voltage at the sine analog input during the auto-teaching procedure. It can be compared with the A.SENS.OFFSET SR entry value.
A.SENS.MAX CE (Only for BLE0) (A)	Volt	This parameter records the maximum offset voltage at the cosine analog input during the auto-teaching procedure. It can be compared with the A.SENS.OFFSET CR entry value.
A.SENS.MIN CE (Only for BLE0 with sin/cos sensor) (A)	Volt	This parameter records the minimum offset voltage at the cosine analog input during the auto-teaching procedure. It can be compared with the A.SENS.OFFSET CR entry value.
MAN.OFFSET ANGLE (Only for BLE0) (A)	0° - 180° (steps of 0.1°)	This parameter gives the possibility to manually adjust the offset angle present between the absolute position sensor and the PMSM rotor orientation. The unit is degrees and the max value is 180°.
MOT.T. T.CUTBACK (A)	0% - 100% (256 steps)	This parameter defines the motor thermal cutback. The control linearly reduces the motor torque basing on the motor temperature. Reference limits of the linear reduction are MAX MOTOR TEMP and TEMP. MOT. STOP. See paragraph 9.14.
BAT.ENERGY SAVER (T, TM, P)	OFF ÷ ON	When set to ON, this parameter enables the possibility to save the battery charge when it has reached a certain value, through a maximum torque reduction.

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.

<table>
<tr><th colspan="3">SPECIAL ADJUST.</th></tr>
<tr><th>Parameter</th><th>Allowable range</th><th>Description</th></tr>
<tr><td>ADJUSTMENT #01
(Read Only)
(A)</td><td></td><td>Gain of the first traction-motor current-sensing amplifier.
NOTE: only Zapi technicians can change this value through a special procedure.</td></tr>
<tr><td>ADJUSTMENT #02
(Read Only)
(A)</td><td></td><td>Gain of the second traction-motor current-sensing amplifier.
NOTE: only Zapi technicians can change this value through a special procedure.</td></tr>
<tr><td>CURR. SENS. COMP
(A)</td><td>OFF ÷ ON</td><td>This parameter enables or disables the linear compensation for the current sensors.
NOTE: only Zapi technicians can change this value through a special procedure.</td></tr>
<tr><td>DIS.CUR.FALLBACK
(A)</td><td>OFF ÷ ON</td><td>This parameter disables or enables current reduction (applied after one minute of traction).
ON = Current reduction is disabled.
OFF = Current reduction is enabled.</td></tr>
<tr><td>SET CURRENT
(Read Only)
(A)</td><td>See table on the right</td><td>(Factory adjusted). This is maximum current that the inverter can provide to the motor.
<table><tr><th>Controller voltage</th><th>Allowable values [Arms]</th></tr><tr><td>24V</td><td>220, 320, 350</td></tr><tr><td>36V/48V</td><td>180, 280, 320</td></tr><tr><td>80V</td><td>200</td></tr></table></td></tr>
<tr><td>SET TEMPERATURE
(A)</td><td>0°C ÷ 255°C
(steps of 1°C)</td><td>This parameter calibrates the controller-temperature reading.</td></tr>
<tr><td>HW BATTERY RANGE
(Read Only)
(A)</td><td>0 ÷ 3
(steps of 1)</td><td>This parameter defines the battery voltage range.
NOTE: only Zapi technicians can change this value.</td></tr>
<tr><td>DUTY PWM CTRAP
(Read Only)
(A)</td><td>0% ÷ 100%</td><td>This parameter defines the duty cycle for overcurrent threshold. Reserved.</td></tr>
</table>

<table>
<tr><th colspan="3">SPECIAL ADJUST.</th></tr>
<tr><th>Parameter</th><th>Allowable range</th><th>Description</th></tr>
<tr><td>ADJUSTMENT #03
(Read Only)</td><td>0% ÷ 255%</td><td>Gain of the pump-motor current-sensing amplifier.
NOTE: only Zapi technicians can change this value through a special procedure.</td></tr>
<tr><td>SET CURRENT PUMP
(Read Only)</td><td>See table on the right</td><td>This is the pump motor maximum current.<table><tr><th>Controller voltage</th><th>Allowable values [Arms]</th></tr><tr><td>24V</td><td>270, 300, 400</td></tr><tr><td>36V/48V</td><td>220, 300</td></tr><tr><td>80V</td><td>200</td></tr></table></td></tr>
<tr><td>PWM AT LOW FREQ
(A)</td><td></td><td>This parameter defines the power-bridge PWM frequency at low speed.
NOTE: only Zapi technicians can change this value through a special procedure.</td></tr>
<tr><td>PWM AT HIGH FREQ
(A)</td><td></td><td>This parameter defines the power-bridge PWM frequency at high speed.
NOTE: only Zapi technicians can change this value through a special procedure.</td></tr>
<tr><td>FREQ TO SWITCH
(A)</td><td>Volt</td><td>(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.</td></tr>
<tr><td>DITHER AMPLITUDE
(A)</td><td>0% ÷ 13%</td><td>This parameter defines the dither signal amplitude. The dither signal is a square wave added to the proportional-valve set-point. In this way the response to set-point variations results optimized. This parameter is a percentage of the valve maximum current. Setting the parameter to 0% means the dither is not used.
The available values are:
0.0%, 1.0%, 2.5%, 4.0%, 5.5%, 7.0%, 8.5%, 10%, 11.5%, 13.0%</td></tr>
<tr><td>DITHER FREQUENCY
(A)</td><td>20.8 Hz ÷ 83.3 Hz</td><td>This parameter defines the dither frequency.
The available values are:
20.8, 22.7, 25, 27.7, 31.2, 35.7, 41.6, 50, 62.5, 83.3</td></tr>
<tr><td>HIGH ADDRESS
(A)</td><td>0 ÷ 4</td><td>This parameter is used to access special memory addresses.</td></tr>
<tr><td>CAN BUS SPEED
(A)</td><td>20 kbps ÷ 500 kbps</td><td>This parameter defines the CAN bus data-rate in kbps.
20, 50, 125, 250, 500</td></tr>
<tr><td>EXTENDED FORMAT
(A)</td><td>OFF, ON</td><td>This parameter defines the CAN bus protocol.</td></tr>
<tr><td>DEBUG CANMESSAGE
(A)</td><td>OFF, ON</td><td>This parameter enables or disables special debug messages.</td></tr>
</table>

SPECIAL ADJUST.		
Parameter	**Allowable range**	**Description**
CONTROLLER TYPE (A)	0 ÷ 15	This parameter defines the controller type: **0 =** Traction AC **1 =** Pump AC **2 =** CAN OPEN AC **3 =** Dual traction AC (master) **4 =** Dual traction AC (slave) **5 =** Traction brushless **6 =** Pump brushless **7 =** CAN OPEN brushless **8 =** Dual traction brushless (master) **9 =** Dual traction brushless (slave) **10 =** Multi-motor traction AC (slave 2) **11 =** Multi-motor traction AC (slave 3) **12 =** Multi-motor traction brushless (slave 2) **13 =** Multi-motor traction brushless (slave 3) **14 =** Gen. set AC (slave 2) **15 =** Gen. set brushless (slave 3) **NOTE:** a mismatch between this parameter and the hardware configuration may lead to a severe malfunctioning of the controller.
SAFETY LEVEL (T, TM, P, CO)	0 ÷ 3	This parameter defines the safety level of the controller, i.e. the functionality of the supervisor microcontroller. **0 =** Supervisor µC does not check any signal. **1 =** Supervisor µC checks the inputs and the outputs. **2 =** Supervisor µC checks the inputs and the motor set-point. **3 =** Supervisor µC checks the inputs, the outputs and the motor set-point.
RS232 CONSOLLE (A)	OFF ÷ ON	This parameter enables or disables the console to change settings. NOTE: only Zapi technicians can change this value.
ID CANOPEN OFST (CO)	0 ÷ 56 (by steps of 8)	This parameter defines the offset of the CANopen frame IDs.
2ND SDO ID OFST (A)	0 ÷ 126 (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 (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 (T, TM, P, CO)	0% ÷ 255% (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 (T, TM, P, CO)	0% ÷ 255% (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 (T, TM, P, CO)	0% ÷ 255% (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.
RESOLVER PULSE (A)		Used for special resolvers. Reserved. Note: only Zapi technicians can change this value.

8.2.5 HARDWARE SETTING

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 SETTING		
Parameter	**Allowable range**	**Description**
TOP MAX SPEED (T, TM, P, CO)	0 Hz ÷ 600 Hz (by steps of 10 Hz)	This parameter defines the maximum motor speed. Factory adjusted.
CONF.POSITIVE LC (A)	0 ÷ 2 (steps of 1)	This parameter defines the positive supply configuration for the main-contactor coil. Factory adjusted. **0:** The positive supply of Main Contactor coil is connected to PEV (pin A3) **1:** The positive supply of Main Contactor coil is connected to KEY (pin A10) **2:** The positive supply of Main Contactor coil is connected to TILLER input (pin A1) NOTE: only Zapi technicians can change this value through a special procedure.

HARDWARE SETTING		
Parameter	**Allowable range**	**Description**
FEEDBACK SENSOR (A)	0 ÷ 6	This parameter defines the type of the adopted speed sensor. Factory adjusted. **0 =** Incremental encoder. **1 =** Sin/cos sensor. **2 =** Incremental encoder + sin/cos sensor. **3 =** Incremental encoder + sin/cos sensor + index. **4 =** PWM absolute sensor + incremental encoder + index. **5 =** Resolver. **6 =** Hall effect sensor (six-step).
POSITIVE E.B. (A)	0 ÷ 2	This parameter defines the hardware configuration for the positive terminal of the electromechanical brake PEB (A2). **0 =** PEB is managed by the smart driver (available for 24V version only). **1 =** PEB comes from the TILLER input (A1). The internal jumper must be properly configured. **2 =** PEB comes from PEV (A3). PEV must be connected to terminal +B of the controller. This is the default configuration for 36/48V and 80V version.
ROTATION CW ENC (A)	OPTION#1 ÷ OPTION#2	It defines how the signal sequence coming from the encoder channels is expected by controller **OPTION#1 =** Channel A anticipates channel B. **OPTION#2 =** Channel B anticipates channel A.
ROTATION CW MOT (A)	OPTION#1 ÷ OPTION#2	It permits to change the sequence in which the motor phases are powered. Factory adjusted. **OPTION#1 =** U-V-W corresponds to forward direction. **OPTION#2 =** V-U-W corresponds to forward direction.
ROTATION CW POS **(Only for BLE0)** (A)	OPTION#1 ÷ OPTION#2	It permits to reverse the direction read by the absolute position sensor. **OPTION#1 =** Sin anticipates cos. **OPTION#2 =** Cos anticipates sin.
ENCODER PULSES 1 (A)	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. The available options are: **32, 48, 64, 80, 64, 128, 256, 512, 1024** NOTE: with standard HW, the capability to use encoders with high number of pulses could be limited depending on the speed. Ask to Zapi technician before to operate on this parameter

HARDWARE SETTING		
Parameter	**Allowable range**	**Description**
ENCODER PULSES 2 (A)	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. The available options are: **32, 48, 64, 80, 64, 128, 256, 512, 1024** NOTE: with standard HW, the capability to use encoders with high number of pulses could be limited depending on the speed. Ask to Zapi technician before to operate on this parameter
MOTOR P. PAIRS 1 (A)	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 (A)	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.

8.3 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 (Master µC)		
Parameter	**Unit of measure (resolution)**	**Description**
KEY VOLTAGE (A)	Volt (0.1 V)	KEY voltage (A10) value measured in real time.
BATTERY VOLTAGE (A)	Volt (0.1 V)	Battery voltage measured in real time across the DC bus.

TESTER (Master µC)		
Parameter	**Unit of measure (resolution)**	**Description**
DC BUS CURRENT (A)	Ampere (1 A)	Estimation of the DC current the inverter is drawing from the battery.
BATTERY CHARGE (A)	Percentage (1%)	Estimation of the battery charge based on the battery voltage.
MOTOR VOLTAGE (A)	Percentage (1%)	Theoretical phase- to- phase voltage to be applied at the motor terminals, as a percentage of the supply voltage. The actual applied voltage is changed by INDEX OVERMOD. (see next item).
INDEX OVERMOD. (A)	Percentage (1%)	Correction applied to the motor-voltage set-point in order to compensate for the actual battery voltage. The actual motor voltage delivered is the product of MOTOR VOLTAGE and INDEX OVEMOD.
FREQUENCY (A)	Hertz (0.1 Hz)	Frequency of the current sine-wave that the inverter is supplying to the motor.
MEASURED SPEED (A)	Hertz (0.1 Hz)	Motor speed measured through the encoder and expressed in the same unit of FREQUENCY (Hz).
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. $Current\ [Arms] = \sqrt[2]{{I_Q}^2 + {I_D}^2}$ $Current\ [Arms] = \sqrt{{I_Q}^2 + {I_D}^2}$
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

TESTER (Master µC)		
Parameter	**Unit of measure (resolution)**	**Description**
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)	Nm (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.
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.
DC PUMP CURRENT (A)	Ampere (1 A)	DC current of the pump motor.
DC PUMP VMN (A)	% (1%)	Voltage applied to the pump motor. Duty cycle of the PWM applied to the motor.
DI0-A1 TILLER SW (T, TM, TS)	OFF/ON	Status of the TILLER/SEAT input (pin A1).
DI1-A7 QI/PB SW (T, TM)	OFF/ON	Status of the quick-inversion/pedal-brake input (pin A7).
DI2-A6 HS SW (T, TM)	OFF/ON	Status of the hard & soft input (pin A6).
DI3-A32 FW SW (T, TM)	OFF/ON	Status of the forward input (pin A32).
DI3-A32 ENABLE (T, TM)	OFF/ON	Status of the digital input 3 on (pin A32).
DI3-A32 FW-INCH (TS)	OFF/ON	Status of the forward input (pin A32), when the inching function is enabled.

TESTER (Master µC)		
Parameter	**Unit of measure (resolution)**	**Description**
DI4-A31 BW SW (T, TM)	OFF/ON	Status of the backward input (pin A31).
DI4-A31 BW-INCH (TS)	OFF/ON	Status of the backward input (pin A31), when the inching function is enabled.
DI5-A19 HORN **(not for BLE0)** (T, TM)	OFF/ON	Status of the digital input 5 (pin A19), dedicated to the horn (not for BLE0).
DI5-A19 LOWER DC **(only for BLE0)** (T, TM)	OFF/ON	Status of the digital input 5 (pin A19), dedicated to the lower function done through a descent proportional valve on A24 (only for BLE0).
DI6-A20 LOWER DC **(not for BLE0)** (T, TM)	OFF/ON	Status of the digital input 6 (pin A20), dedicated to the lower function done through a descent proportional valve on A24 (not for BLE0).
DI7-A35 LFT/E DC **(only for COMBIAC0)** (T, TM)	OFF/ON	Status of the digital input 7 (pin A35), dedicated to the lift function (only for COMBIAC0).
DI7-A35 ENAB. DC (T, TM)	OFF/ON	Status of the digital input 7 (pin A35) dedicated to the enable function (only for ACE0).
DI8-A17 SPD1 DC (T, TM)	OFF/ON	Status of the spare digital input 8 (pin A17).
DI9-A29 PURID DC (T, TM)	OFF/ON	Status of the digital input 9 (pin A29).
DI10-A16 SPD2 DC (T, TM)	OFF/ON	Status of the spare digital input 10 (pin A16).
DI11-A18 CUTBAC1 (T, TM)	OFF/ON	Status of the spare digital input 11 (pin A18).
DI12-A21 CUTBAC2 (T, TM)	OFF/ON	Status of the spare digital input 12 (pin A21).
DI0-A1 SEAT SW (P)	OFF/ON	Status of the TILLER/SEAT input (pin A1).
DI1-A7 SPD1 SW (P)	OFF/ON	Status of the digital input 1 (pin A7), dedicated to the 1st pump speed (for ACE0/COMBIAC0 configured as pump controller).

TESTER (Master µC)		
Parameter	**Unit of measure (resolution)**	**Description**
DI2-A6 HYDRO SW (P)	OFF/ON	Status of the digital input 2 (pin A6), dedicated to the hydraulic request (for ACE0/COMBIAC0 configured as pump controller).
DI3-A32 LFT/E SW (P)	OFF/ON	Status of the digital input 3 (pin A32), dedicated to the lift function (for ACE0/COMBIAC0 configured as pump controller).
DI4-A31 LOWER SW (P)	OFF/ON	Status of the digital input 4 (pin A31), dedicated to the lowering function (for ACE0/COMBIAC0 configured as pump controller).
DI5-A19 SPD2 SW (P)	OFF/ON	Status of the digital input 5 (pin A19), dedicated to the 2nd pump speed (for ACE0/COMBIAC0 configured as pump controller).
DI6-A20 FREE (P)	OFF/ON	Status of the digital input 6 (pin A20), free for custom functions (for ACE0 configured as pump controller).
DI7-A35 SPD3 SW (P)	OFF/ON	Status of the digital input 7 (pin A35), dedicated to the 3rd pump speed (for ACE0/COMBIAC0 configured as pump controller).
DI8-A17 SPD4 SW (P)	OFF/ON	Status of the digital input 8 (pin A17), dedicated to the 4th pump speed (for ACE0/COMBIAC0 configured as pump controller).
DI9-A29 SPD5 SW (P)	OFF/ON	Status of the digital input 9 (pin A29), dedicated to the 5th pump speed (for ACE0/COMBIAC0 configured as pump controller).
DI10-A16 CUTBAC1 (P)	OFF/ON	Status of the digital input 10 (pin A16), dedicated to the pump cutback (for ACE0/COMBIAC0 configured as pump controller).
DI11-A18 FREE (P)	OFF/ON	Status of the digital input 11 (pin A18), free for custom functions (for ACE0/COMBIAC0 configured as pump controller).
DI12-A21 FREE (P)	OFF/ON	Status of the digital input 12 (pin A21), free for custom functions (for ACE0/COMBIAC0 configured as pump controller).
NODE ID (CO)	0 ÷ 56	Node ID of the controller over CAN bus.
TARGET SPEED (CO)	10·Hz	Speed setpoint transmitted over CAN bus. It is expressed in tenths of Hz.
BRAKING REQUEST (CO)	0 ÷ 255	Braking setpoint transmitted over CAN bus.
CONTROL WORD (CO)	0 ÷ 65535	Control word transmitted over CAN bus.

TESTER (Master µC)		
Parameter	**Unit of measure (resolution)**	**Description**
STATUS WORD (CO)	0 ÷ 65535	Status word travelling over CAN bus.
WARNING SYSTEM (CO)	0 ÷ 65535	Warning code (in case of warning).
TARGET EVP1 (CO)	% (1%)	Setpoint of the proportional electrovalve EVP1 transmitted over CAN bus.
TARGET EVP2 (CO)	% (1%)	Setpoint of the proportional electrovalve EVP2 transmitted over CAN bus.
TARGET PUMP (CO)	% (1%)	Setpoint of the DC pump transmitted over CAN bus.
TORQUE REQ. (CO)	% (255 steps)	Torque setpoint of the AC motor transmitted over CAN bus, expressed as percentage of the maximum torque.
TORQUE BRK REQ. (CO)	% (255 steps)	Breaking torque setpoint of the AC motor transmitted over CAN bus, expressed as percentage of the maximum torque.
A15 POT#1 (A)	Volt (0.01 V)	Voltage of the analog input 1 (pin A15).
A30 POT#2 (A)	Volt (0.01 V)	Voltage of the analog input 2 (pin A30).
D11-A18 POT#3 (A)	Volt (0.01 V)	Voltage of the analog input 3 (pin A11), if the associated hardware is configured as analog input.
D12-A21 POT#4 (A)	Volt (0.01 V)	Voltage of the analog input 4 (pin A21), if the associated hardware is configured as analog input.
SIN FB. INPUT **(Only for BLE0 with sin/cos sens)** (A)	Volt (0.01 V)	Voltage of the sine input (pin A21).
COS FB. INPUT **(Only for BLE0 with sin/cos sens)** (A)	Volt (0.01 V)	Voltage of the cosine input (pin A18).
A24 SET EVP (A)	Percentage (1%)	Setpoint of the EVP1 output (pin A24).
A23 SET EVP2 (A)	Percentage (1%)	Setpoint of the EVP2 output (pin A23).

TESTER (Master µC)		
Parameter	**Unit of measure (resolution)**	**Description**
A9 OUTPUT EV1 (A)	OFF/ON	Status of the EV1 output (pin A9).
A11 OUTPUT EV2 (A)	OFF/ON	Status of the EV2 output (pin A11).
A33 OUTPUT EV3 (A)	OFF/ON	Status of the EV3 output (pin A33).
A34 OUTPUT EV4 (A)	OFF/ON	Status of the EV4 output A34.
A8 OUTPUT EV5 (A)	OFF/ON	Status of the EV5 output A8.
A26 OUTPUT HORN (A)	OFF/ON	It shows the status of the HORN output (pin A26)..
A12 MAIN CONT. (A)	% (1%)	Voltage applied over the main contactor coil. It corresponds to the duty cycle value of PWM applied, expressed as percentage.
A4 ELEC.BRAKE (A)	% (1%)	Voltage applied over the electromechanical brake coil. It corresponds to the duty cycle value of PWM applied, expressed as percentage.
CTRAP HW (A)	Units (1)	Counter showing the number of occurrences of hardware-overcurrent detection.
CTRAP THRESOLD (A)	Volt (0.01 V)	Threshold voltage of the overcurrent detection circuit.
A.SENS.OFFSET SR **(Only for BLE0 with sin/cos sens)** (A)	Digital units (1)	Voltage offset of the sine signal, acquired during the automatic acquisition of the sin/cos sensor.
A.SENS.OFFSET CR **(Only for BLE0 with sin/cos sens)** (A)	Digital units (1)	Voltage offset of the cosine signal, acquired during the automatic acquisition of the sin/cos sensor.
ANGLE OFFSET **(Only for BLE0 with sin/cos sens)** (A)	Degrees (0.1°)	Angular offset between the stator and the sin/cos sensor.

TESTER (Master µC)		
Parameter	**Unit of measure (resolution)**	**Description**
ANGLE OFFSET ENC **(Only for BLE0 with encoder)** (A)	Degrees (0.1°)	Angular offset between the stator and the index signal (in case of ABI encoder, i.e. encoder with index – or zero – signal).
ROTOR POSITION **(Only for BLE0)** (A)	Degrees (0.1°)	Real-time absolute orientation of the rotor, expressed in degrees.
TRUCK SPEED (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 (T, TM, CO)	km (1 km)	Odometer: overall distance traveled by the truck.
CPU TIME F US (A)	-	Reserved for Zapi technicians use.
CPU TIME M US (A)	-	Reserved for Zapi technicians use.

8.3.2 TESTER – Supervisor microcontroller

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

TESTER (Supervisor µC)		
Parameter	**Unit of measure (resolution)**	**Description**
MEASURED SPEED (A)	Hertz (0.1 Hz)	Motor speed measured through the encoder and expressed in the same unit of FREQUENCY (Hz).
DI0-A1 (A)	OFF/ON	Status of the digital input 0 (pin A1).
DI1-A7 (A)	OFF/ON	Status of the digital input 1 (pin A7).
DI2-A6 (A)	OFF/ON	Status of the digital input 2 (pin A6).
DI3-A32 (A)	OFF/ON	Status of the digital input 3 (pin A32).
DI4-A31 (A)	OFF/ON	Status of the digital input 4 (pin A31).
DI5-A19 (A)	OFF/ON	Status of the digital input 5 (pin A19).
DI6-A20 (A)	OFF/ON	Status of the digital input 6 (pin A20).
DI7-A35 (A)	OFF/ON	Status of the digital input 7 (pin A35).
DI8-A17 (A)	OFF/ON	Status of the digital input 8 (pin A17).
DI9-A29 (A)	OFF/ON	Status of the digital input 9 (pin A29).
DI10-A16 (A)	OFF/ON	Status of the digital input 10 (pin A16).
DI11-A18 **(Not for BLE0)** (A)	OFF/ON	Status of the digital input 11 (pin A18).
DI12-A21 **(Not for BLE0)** (A)	OFF/ON	Status of the digital input 12 (pin A21).

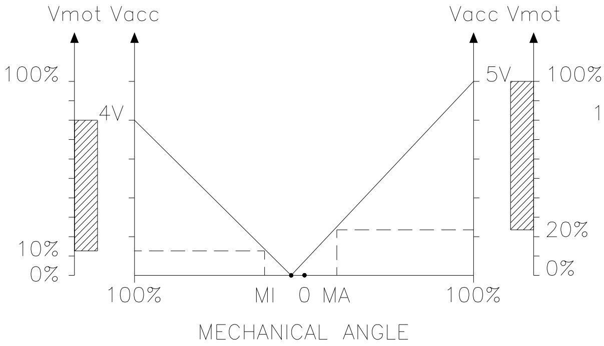
TESTER (Supervisor µC)		
Parameter	**Unit of measure (resolution)**	**Description**
A15 POT#1 (A)	Volt (0.01 V)	Status of the analog input 1 (pin A15).
A30 POT#2 (A)	Volt (0.01 V)	Status of the analog input 2 (pin A30).
D11-A18 POT#3 (A)	Volt (0.01 V)	Status of the analog input 3 (pin A18), when the associated hardware is configured as analog input.
D12-A21 POT#4 (A)	Volt (0.01 V)	Status of the analog input 3 (pin A21), when the associated hardware is configured as analog input.
WARNING SYSTEM (CO)	-	Warning code (in case of warning).

9 OTHER FUNCTIONS

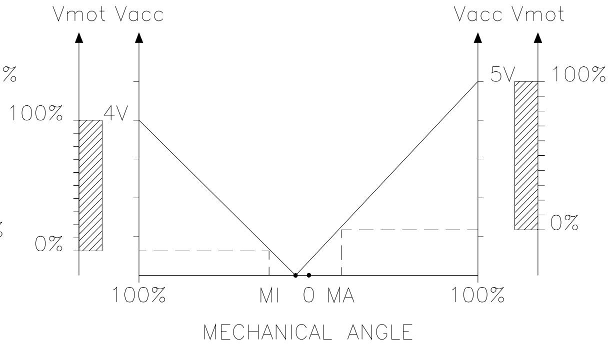
9.1 PROGRAM VACC function

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 or 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 the 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.

  <u>Case 1</u> (black trace in the graph):
  - Final-speed setpoint = 100 Hz
  - ACCEL DELAY = 2.5 s

  Acceleration time results 2.5 s.

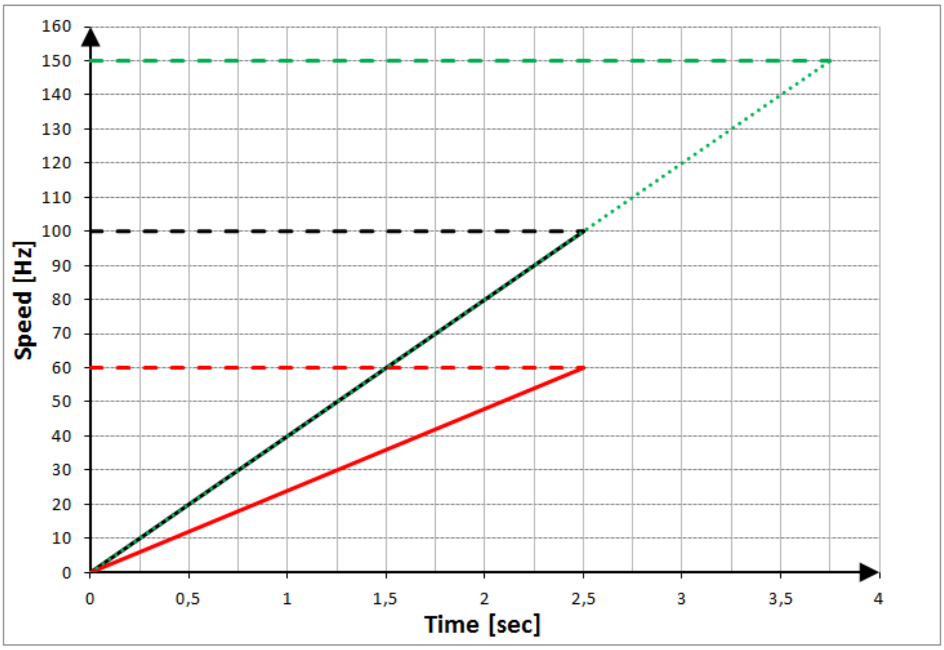
  <u>Case 2</u> (red trace in the graph):
  - Final-speed setpoint = 60 Hz
  - ACCEL DELAY = 2.5 s

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

  <u>Case 3</u> (green trace in the graph):
  - Final-speed setpoint = 150 Hz
  - ACCEL DELAY = 2.5 s

  Acceleration time results:

$$\mathrm{Acceltime[sec]} = \frac{150\mathrm{Hz}}{100\mathrm{Hz}} \cdot \mathrm{Accelerdelay} = 3{,}75\mathrm{sec}$$



Acceleration time.

9.5 Braking time

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.

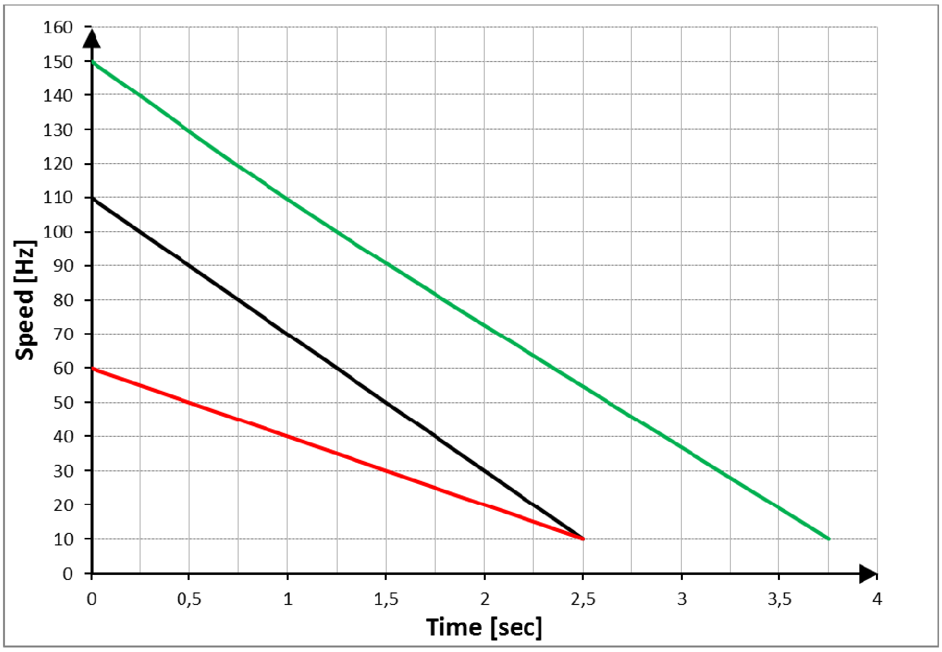
Case 2 (red trace in the graph):
- Initial speed = 60 Hz
- Final-speed setpoint = 10 Hz
- DECEL. BRAKING = 2.5 s

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:

$$\mathrm{Deceltime[sec]} = \frac{150\mathrm{Hz}}{100\mathrm{Hz}} \cdot \mathrm{DecelBraking} = 3{,}75\mathrm{sec}$$

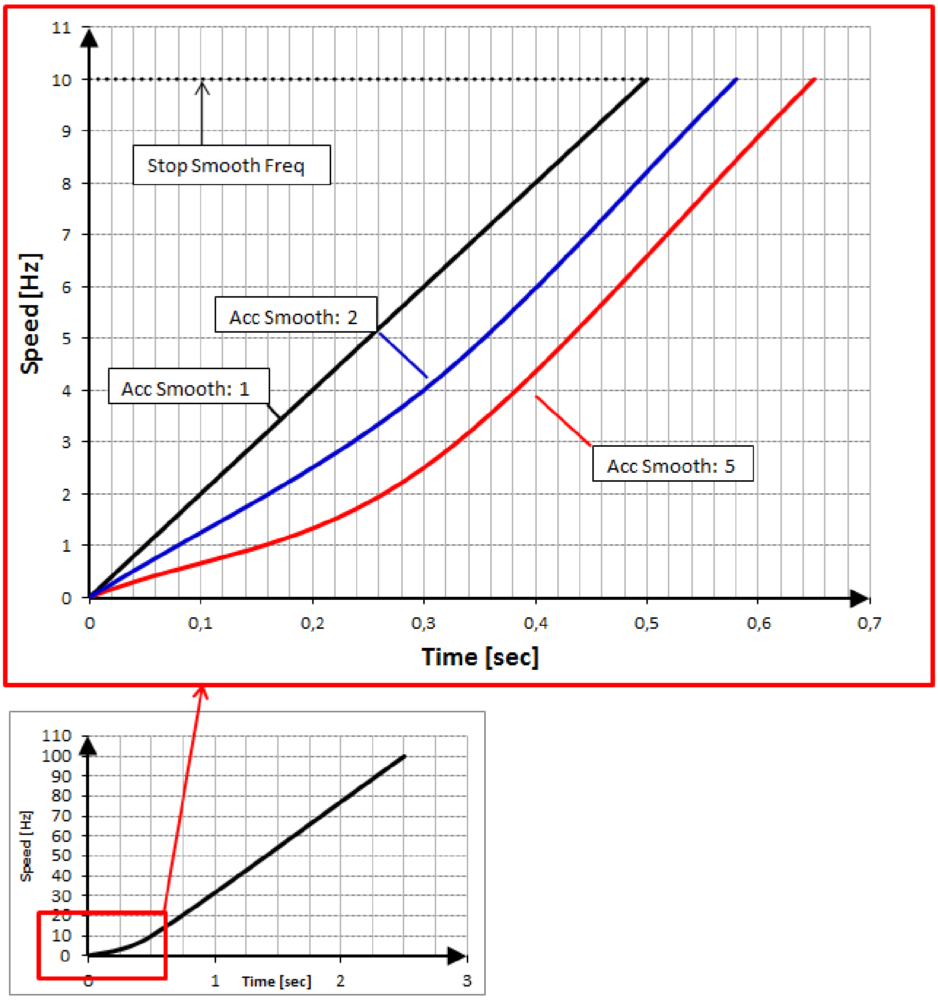


Braking delay.

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.

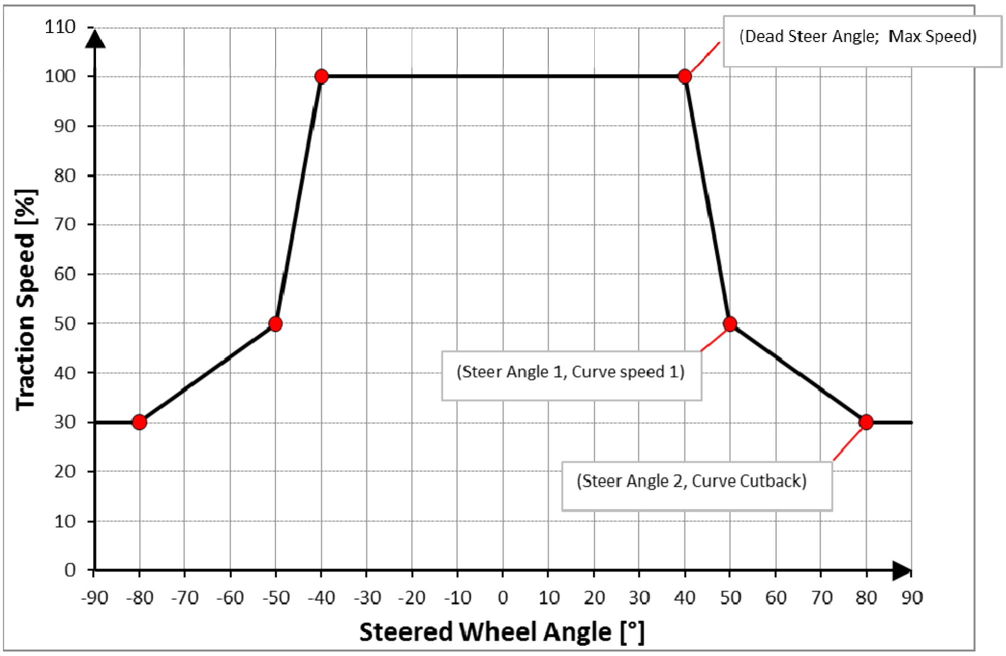
The profile is valid both for positive and negative angle values.

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 Description of the throttle regulation

ACE0/CombiAC0 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.

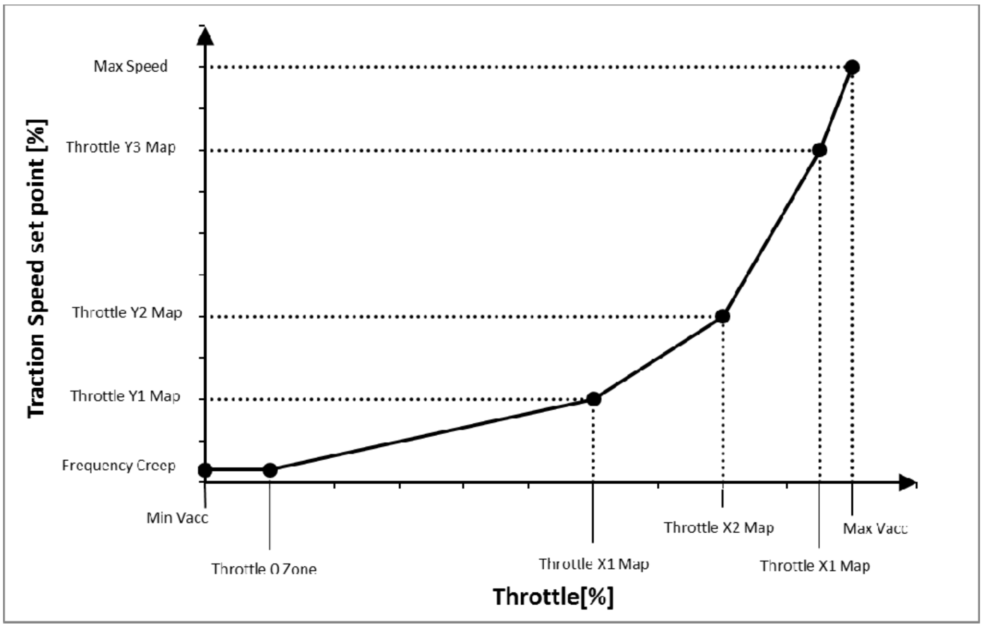
For the definition of such response, the following parameters are used:

- 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.



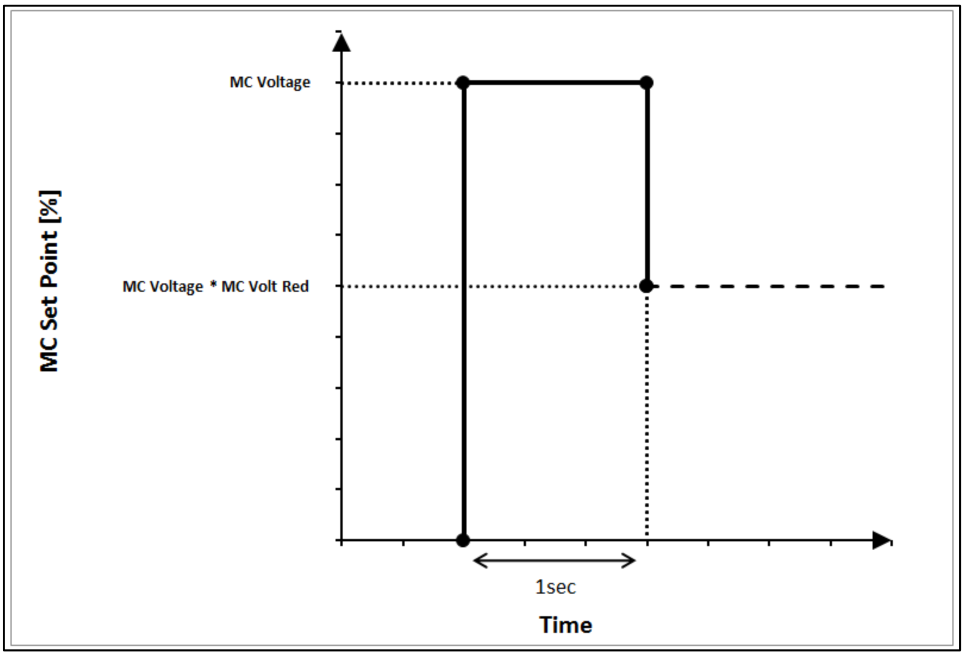
Throttle profile.

9.9 NMC & NEB output

For the NMC 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

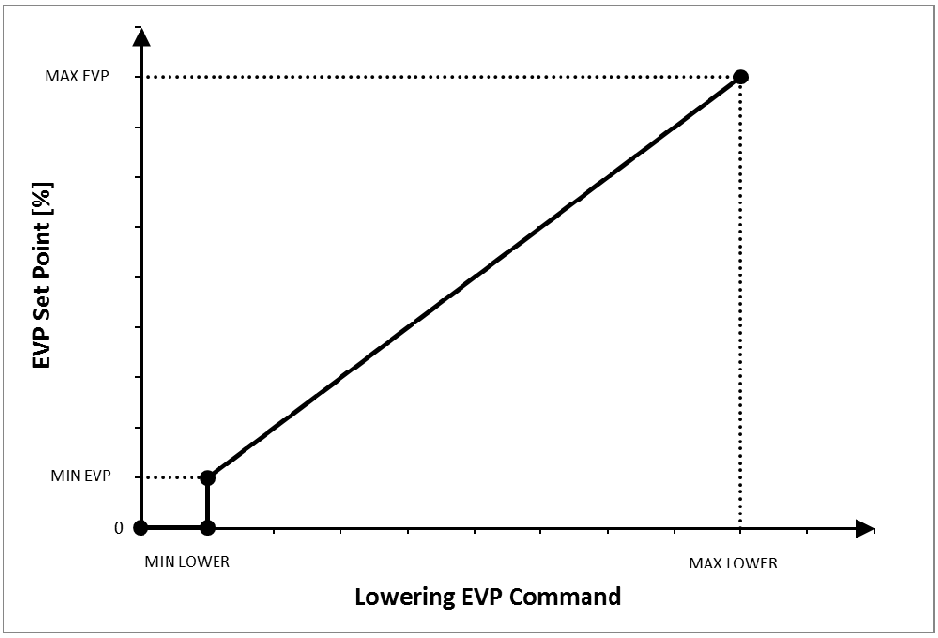
Measure of the battery voltage, together with the charge percentage at the time of the voltage sampling, give information about the instantaneous battery current.

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.

4) 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 EVP Setup

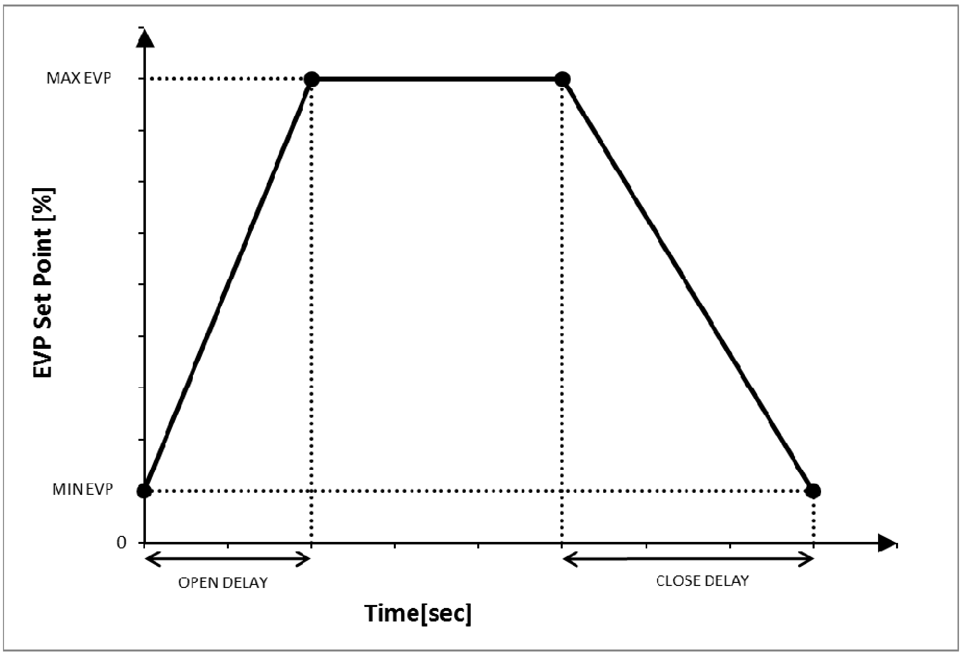
When the EVP is set as ANALOG (see paragraph 8.2.1) the output is managed as explained in the following example.
Considering the case in that the EVP request is concerning the lowering valve, the MIN EVP parameter (see paragraph 8.2.1) determines the minimum current set point applied to the valve when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



EVP management

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

The dynamic delay seen during the modification of the current set point, in both cases, ANALOG Valve and ON/OFF Valve, is dependent by the OPEN DELAY and CLOSE DELAY parameters (see paragraph 8.2.1).
OPEN DELAY determines the current increase rate on EVP and it sets the time needed to increase the current to the maximum permitted value.
CLOSE DELAY determines the current decrease rate on EVP and sets the time needed to decrease the current from the maximum value to minimum.



EVP Set point.

Example 1:
The lowering output is set to ANALOG and the descent request consists of a step whose width corresponds to MAX EVP.

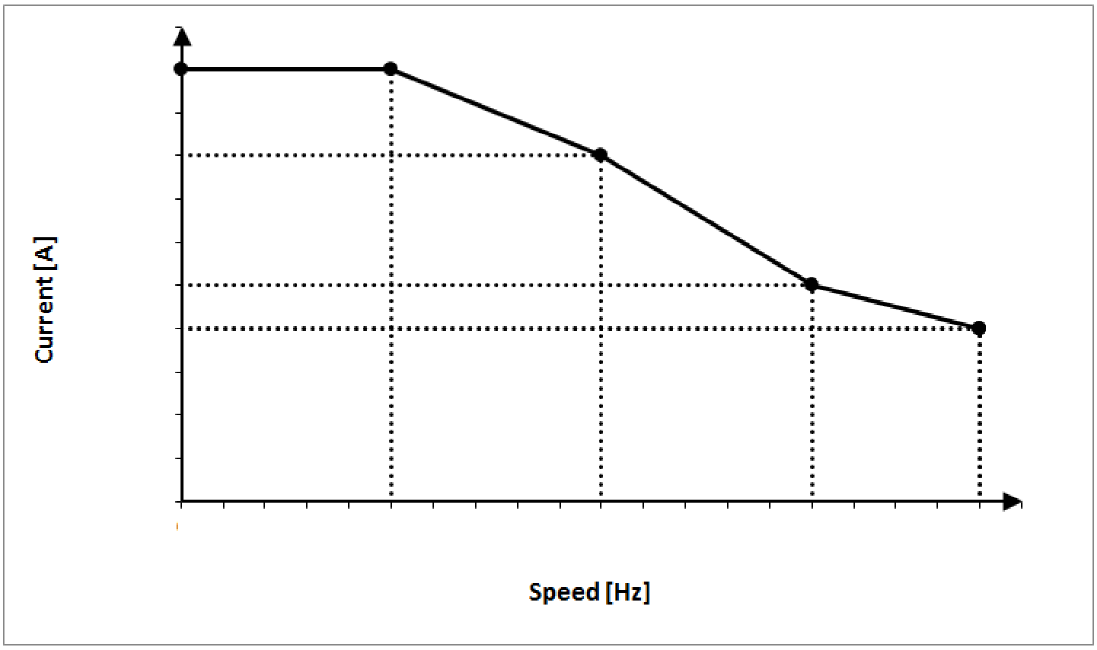
The current is immediately set to the MIN EVP and then it is increased up to MAX EVP in the time set by the OPEN DELAY parameter.
In the same way, if the actual set point applied is the maximum and the lowering request is removed all at once, the current is reduced to minimum with a time delay equal to CLOSE DELAY and then is set to zero.

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

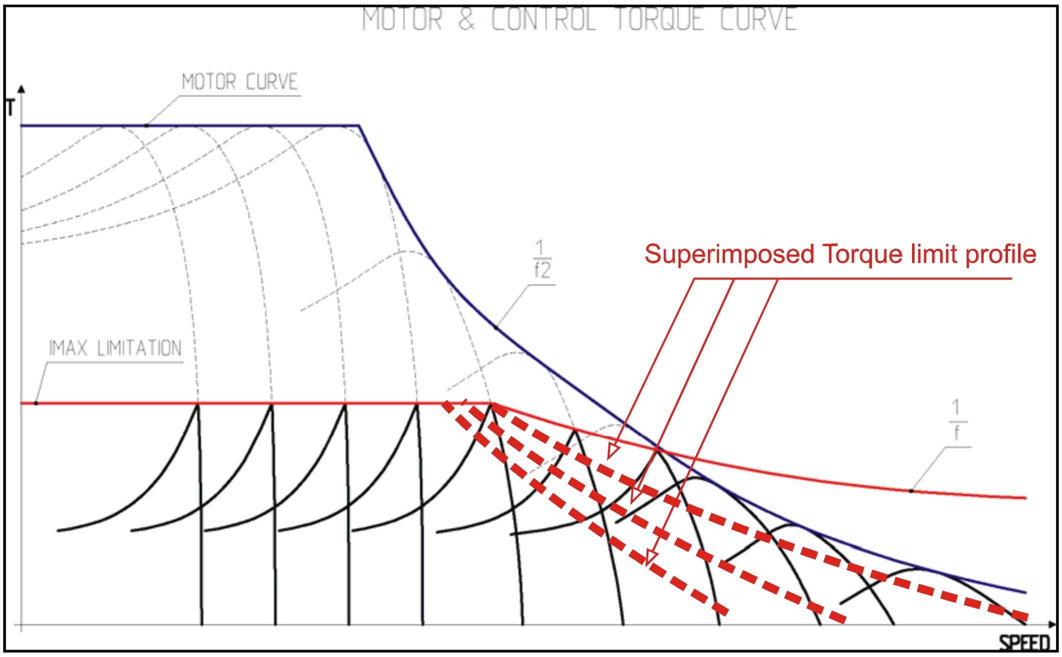
9.12 Torque Profile

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.
Superimposing a limiting profile to the maximum torque as to get different drive performances (Eco mode, Medium performance, High performance).



Torque profile.



Torque curves.

9.13 Steering Table

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

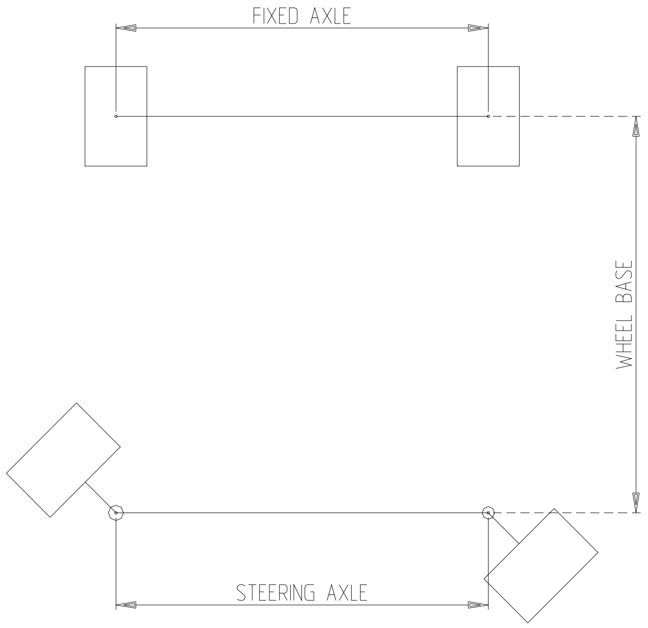
The STEER TABLE parameter defines whether to adopt a custom or predefined steering table:

- **NONE** = custom steering table, according to the following parameters:
  - WHEELBASE MM: distance between the front axle and the rear axle of the truck.
  - FIXED AXLE MM: axle width of the axle where the fixed wheels are.
  - 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.

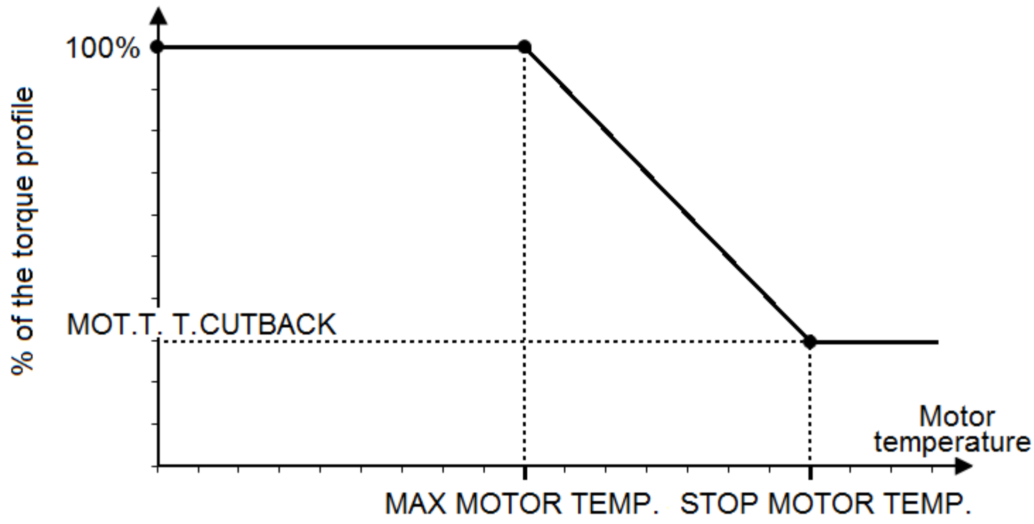
9.14 Motor thermal protection

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 9.12) 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.

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10 DIAGNOSTIC SYSTEM

The diagnostic system of ACE0/CombiAC0 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.

Detailed information about each alarm is given in paragraphs 10.2 and 10.4.

10.1 ALARMS menu

The ALARMS logbook in the 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 it is possible to stack different types of alarms with the following information:

1) the alarm code;
2) the number of times each alarm has consecutively occurred;
3) the hour-meter value at the last occurrence of each alarm;
4) the inverter temperature at the first occurrence of each alarm.

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

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.

For simple visual diagnosis of system faults and for monitoring the system status, a red LED is provided on the body of the controller. It is ON at the start-up and then it stays continuously OFF when there is no fault; when there is a fault it flashes several times, with a repeated pattern that identifies a specific alarm.

10.2 Diagnoses

The microcontroller constantly monitors the inverter and carries out a diagnostic procedure on the main functions.
For simple visual diagnosis of system faults and to monitor system status, a red LED is provided on the body of the controller.

Alarm LED

At start-up it is turned ON for 2 seconds and then it stays continuously OFF when there is no fault.
In case of fault it produces flash codes displaying all the active faults in a repeating cycle.
Each code consists of two digits (see chapter 10) shown through the following sequence:

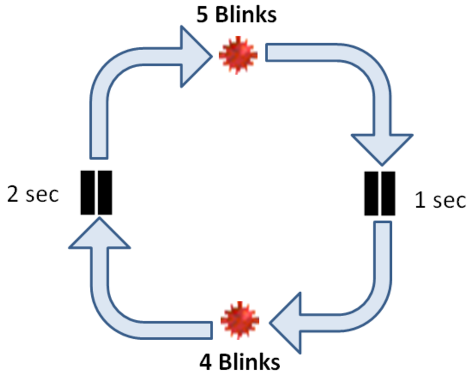
1) the LED blinks as much times as the first digit value
2) it makes a pause of 1 sec
3) it blinks as much times as the second digit value.

The sequence it is repeated after a pause of 2 sec

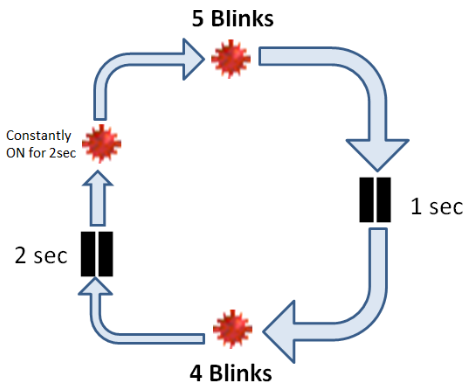
In case of fault concerning supervisor uC the sequence is the same with the only difference that LED stays ON for 2 sec before to start for flashing the appropriate code.

Examples:

- Alarm 54 on master uC



- Alarm 54 on supervisor uC



The diagnosis is made in 4 points:

1) Diagnosis on start-up that checks: watchdog circuit, current sensor, capacitor charging, phase's voltages, contactor drives, can-bus interface, if the switch sequence for operation is correct and if the output of the accelerator unit is correct.

2) Standby diagnosis in standby that checks: watchdog circuit, phase's voltages, contactor driver, current sensor, can-bus interface.

3) Diagnosis during operation that checks: watchdog circuits, contactor driver, current sensors, can-bus interface.

4) Continuous diagnosis that check: temperature of the inverter, motor temperature.

Diagnosis is provided in two ways: the console can be used, which gives detailed information about the failure, but the failure code is also sent on the CAN bus.

10.3 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 on 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

Error code	Effect	Condition	Restart procedure	MDI / LED CODE	CAN OPEN CODE	ZAPI CODE
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
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
EVP2 DRIVER OPEN	MC is opened (the command is released), EB is applied, Traction/Pump, valves stopped	Start-up, stand-by, running	Valves request	10	FFB8	184
EVP2 COIL OPEN	Valves stopped	Start-up, stand-by, running	Valves or Traction/Pump request	10	50F2	182
EVP2 DRIV. SHORT	MC is opened , EB is applied, EVP stopped	Start-up, stand-by, running	Traction/Pump request	10	50F3	183
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

Error code	Effect	Condition	Restart procedure	MDI / LED CODE	CAN OPEN CODE	ZAPI CODE
COIL SHOR. EVAUX	Valves stopped	Start-up, stand-by, running	Valves request	21	FFF1	241
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
AUX BATT. SHORT.	None	Start-up, stand-by, running		27	5001	194
PUMP VMN LOW	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up	Valves or Traction/Pump request	28	FF1C	28
PUMP VMN HIGH	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up	Valves or Traction/Pump request	29	FF1D	29
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
PUMP VMN NOT OK	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up	Valves or Traction/Pump request	33	FFBE	190
HW FAULT EB.	MC is opened, EB is applied, Traction/Pump stopped	Start-up	Key re-cycle	34	FFE5	229
POSITIVE LC OPEN	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up, stand-by, running	Valves or Traction/Pump request	35	FFD5	213
FIELD ORIENT. KO	MC is opened, EB is applied, Traction/Pump, valves stopped	Running	Valves or Traction/Pump request	36	FFFD	253
CONTACTOR CLOSED	MC is not closed (command is not activated), EB is applied, Traction/Pump stopped	Start-up	Valves or Traction/Pump request	37	5442	37
CONTACTOR OPEN	MC is opened, EB is applied, Traction/Pump, valves stopped	Start-up, stand-by, running	Valves or Traction/Pump request	38	5441	38
POWER MISMATCH	Traction is stopped, EB is applied, MC is opened	Running	Traction/Pump request	39	FFD4	212
EB. DRIV.SHRT.	MC remains closed, EB is applied (the command is released), Traction/Pump, valves stopped	Stand-by, running	Valves or Traction/Pump Request	40	3222	254
WRONG SET BAT.	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up		41	3100	251
WRONG KEY VOLT.	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up		41	3101	170
EB. DRIV.OPEN	MC remains closed, EB is applied (the command is released), Traction/Pump, valves stopped	Running	Valves or Traction/Pump Request	42	3224	246
EB. COIL OPEN	MC remains closed, EB is applied (the command is released), Traction/Pump, valves stopped	Start-up, Stand-by, running	Valves or Traction/Pump Request	43	FFD8	216
WAIT MOTOR STILL	MC is not closed, EB is applied, Traction/Pump stopped	Start-up		45	FF9B	155

Error code	Effect	Condition	Restart procedure	MDI / LED CODE	CAN OPEN CODE	ZAPI CODE
WAIT MOT.P STILL	Valve, pump, traction stopped, LC opened, EB applied	Start-up		45	FFBA	186
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
PUMP VACC NOT OK	Traction/Pump motor is stopped	Start-up, stand-by, running	Lift/lower potentiometer at rest	50	FFBC	188
TILLER OPEN	LC opens	Start-up, stand-by, running	Valves or Traction/Pump Request	51	0000	228
PUMP I=0 EVER	MC is open, EB is applied (the command is released), DC pump stopped	Running	Pump request	52	2312	52
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
PUMP I NO ZERO	MC is open, EB is applied (the command is released), DC pump stopped	Running	Pump request	56	FFBF	191
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	Traction/Pump Request	63	FFCC	204
TILLER ERROR	Traction stopped, EB applied	Stand-by, running	H&S input released	64	FFB9	185
MOTOR TEMPERAT.	Maximum current is linearly reduced (see paragraph 9.14) and speed is reduced to a fixed value.	Start-up, stand-by, running		65	4110	65
MOTOR TEMP. STOP	EB is applied, Traction/Pump, valves stopped	Start-up, stand-by, running		65	FFB2	178
NO CAN MSG.	MC is opened, EB is applied, Traction/Pump, valves stopped	Start-up, stand-by, running	Valves or Traction/Pump request	67	8130	248
SENS MOT TEMP KO	Maximum current is reduced according to parameter MOT.T. T.CUTBACK and speed is reduced to a fixed value.	Start-up, stand-by, running		68	4311	218
SMARTDRIVER KO	MC is not closed, Traction/Pump, valves stopped	Start-up	Traction request	69	3302	193
EPS RELAY OPEN	Traction/Pump motor is stopped	Start-up, stand-by, Running	Valves or Traction/Pump request	70	FFCD	205
WRONG RAM MEM.	MC is opened, EB is applied, Traction/Pump, valves stopped	Stand-by	Key re-cycle	71	FFD2	210
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

Error code	Effect	Condition	Restart procedure	MDI / LED CODE	CAN OPEN CODE	ZAPI CODE
CONTACTOR DRIVER	MC is opened (the command is released), EB is applied, Traction/Pump, valves stopped	Start-up, stand-by, running	Valves or Traction/Pump request	75	3221	75
MC-EF COIL SHOR.	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
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	Accelerator at rest	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
POS. EB. SHORTED	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up	Traction request	84	3223	195
VACC OUT RANGE	Traction/Pump motor is stopped	Start-up, Stand-by, Running	Traction/Pump request	85	FFE2	226
VDC OFF SHORTED	MC is not closed, EB is applied, Traction/Pump, valves stopped	Start-up, Stand-by, Running	Key re-cycle	88	FFC8	200
POWERMOS SHORTED	MC is opened, EB is applied, traction/pump stopped	Start-up	Key re-cycle	89	FFE9	233
PUMP VACC RANGE	DC Pump motor is stopped	Start-up, stand-by	Pump request	90	FFC0	192
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
TORQUE PROFILE	EB is applied, Traction/Pump motor is stopped	Start-up, stand-by	Valves or Traction/Pump request	98	FFC9	201
CTRAP THRESHOLD	MC is opened, EB is applied, Traction/Pump, valves stopped	Start-up, stand-by, running	Valves or Traction/Pump request	99	FFEB	235

10.3.1 Troubleshooting of alarms from master μC

ACQUIRE ABORT *(MDI/LED code = 2)*

Cause:

The acquiring procedure relative to the absolute feedback sensor aborted.

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.

ACQUIRE END *(MDI/LED code = 2)*

Cause:

Absolute feedback sensor acquired.

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

Cause

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

Troubleshooting

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

AUX BATT. SHORT. *(MDI/LED code = 27)*

Cause:

The voltage on PEB output (pin A2) is at high value even if it should not. For the versions where the smart driver is not installed (36/48V and 80V), it is possible to decide where the positive supply for pin A2 comes from by choosing a dedicated hardware configuration. The parameter POSITIVE E.B. has to be set in accordance with the hardware configuration (see paragraph 8.2.5), because the software makes a proper diagnosis depending on the parameter; a wrong setting could generate a false fault. The available choices are:

- 0 = PEB is managed by the smart driver (available for 24V version only).
- 1 = PEB comes from the TILLER input (A1).
- 2 = PEB comes from PEV (A3). PEV must be connected to terminal +B of the controller. This is the default configuration for 36/48V and 80V version.

This alarm can only appear if POSITIVE E.B. is set as 1 TILLER/SEAT.

Troubleshooting:

- Verify that the parameter POSITIVE E.B. is set in accordance with the actual coil positive supply (see paragraph 8.2.5).
- In case no failures/problems have been found, the problem is in the controller, which has to be replaced.

BATTERY LOW *(MDI/LED code = 0)*

Cause:

Parameter BATTERY CHECK is other than 0 (SET OPTION list, paragraph 8.2.2) and battery charge is evaluated to be lower than BATT.LOW TRESHLD (ADJUSTMENTS list, paragraph 8.2.3).

Troubleshooting:

- Check the battery charge and charge it if necessary.

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

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 the controller is in CAN OPEN configuration (see parameter CONTROLLER TYPE in SPECIAL ADJUST. list, paragraph 8.2.4).

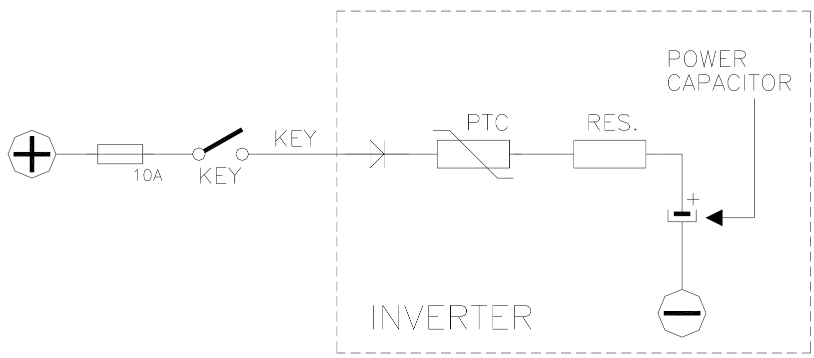
Troubleshooting

- 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)*

Cause

It is related to the capacitor-charging system:



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 A4) 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. EVAUX *(MDI/LED code = 21)*

Cause:

This alarm occurs when an overload of the EV drivers occurs.

Troubleshooting:

- Check the connections between the controller outputs and the loads.
- Collect information about characteristics of the coils connected to the drivers 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 A12) 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 NMC (A12) 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 (A4) and the EB positive terminal PEB (A2).

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 EVP output (A24) 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 DRIVER OPEN *(MDI/LED code = 9)*

Cause:
The EVP driver 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.

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

Cause
- The EVP driver (output A24) 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:
    - the voltage applied across the EVP coil,
    - the current in the coil,
    - features of the coil.

Ask for assistance to Zapi in order to verify that the software diagnoses are in accordance with the type of coil employed.
If the problem is not solved, it could be necessary to replace the controller.

EVP2 COIL OPEN *(MDI/LED code = 10)*

Cause:
No load is connected between the EVP2 output (A23) and the electrovalve positive terminal.

Troubleshooting:
- Check the EVP2 condition.
- Check the EVP2 wiring.

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

EVP2 DRIVER OPEN *(MDI/LED code = 10)*

Cause:

The EVP2 driver is not able to drive the EVP2 coil. The device itself or its driving circuit is damaged.

Troubleshooting:

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

EVP2 DRIV. SHORT. *(MDI/LED code = 10)*

Cause

- The EVP2 driver (output A23) is shorted.
- The microcontroller detects a mismatch between the valve set-point and the feedback of the EVP2 output.

Troubleshooting

- Check if there is a short circuit or a low-impedance conduction path between the negative of the coil and -B.
- Collect information about:
    - the voltage applied across the EVP2 coil,
    - the current in the coil,
    - features of the coil.

Ask for assistance to Zapi in order to verify that the software diagnoses are in accordance with the type of coil employed.

- If the problem is not solved, it could be necessary to replace the controller.

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 A4) is found to be faulty. The hexadecimal value “XX” facilitates Zapi technicians debugging the problem.

Troubleshooting:

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

HW FAULT EV. XX *(MDI/LED code = 16)*

Cause:

At start-up, the hardware circuit dedicated to enable and disable the EV drivers 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 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 A12) 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 NMC output A12 and the positive voltage (for example the KEY voltage).

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 (A10). 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 one or more EV outputs and the positive terminal PEV (pin A3). For the meaning of code “XX”, refer to paragraph 10.510.5.

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

OVERLOAD *(MDI/LED code = 57)*

Cause
The motor current has 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).

POS. EB. SHORTED *(MDI/LED code = 84)*

Cause:

The voltage on pin A2 is high even if the smart driver is turned OFF.

Troubleshooting:

- Verify that the parameter POSITIVE E.B. is set in accordance with the actual coil positive supply (see paragraph 8.2.5).
- Check if there is a short or a low impedance path between pin A2 and of the +B. In case no failures/problems have been found, the problem is in the controller, which has to be replaced.

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.

PUMP VACC NOT OK *(MDI/LED code = 50)*

Cause:

The minimum voltage of the lift potentiometer is not correctly set.

Troubleshooting:

It is suggested to repeat the acquiring procedure of MIN LIFT and MAX LIFT (see paragraph 9.2).

PUMP VMN LOW *(MDI/LED code = 28)*

Cause:

The pump motor output is lower than expected, considering the PWM duty cycle applied.

Troubleshooting:

A) If the problem occurs at start up (the LC does not close at all), check:

- Motor internal connections;
- Motor power cables connections;
- If the motor connection are OK, the problem is inside the controller.

B) If the problem occurs after closing the LC (the LC closes and then opens back again), check:

- Motor internal connections;
- If motor windings/cables have leakages towards truck frame;
- If no problem are found on the motors, the problem is inside the controller.

C) If the alarm occurs during motor running, check:

- Motor internal connections;
- If motor windings/cables have leakages towards truck frame;
- That the LC power contact closer properly, with a good contact;
- If no problem are found on the motors, the problem is inside the controller, it is necessary to replace the logic board.

PUMP VMN HIGH *(MDI/LED code = 29)*

Cause:

This test is carried out when the pump motor is turning (PWM applied). The pump motor output is higher than expected, considering the PWM applied.

Troubleshooting:

- Motor internal connections
- If motor windings/cables have leakages towards truck frame
- If no problem are found on the motors, the problem is inside the controller, it is necessary to replace the logic board.

PUMP VMN NOT OK *(MDI/LED code = 33)*

Cause:

Switching the LC on, the software checks the output voltage on -P connector, and expects that it is at a “steady state” value (if DC PUMP option is set to ON, see paragraph 8.2.1 – HYDRO SETTINGS).
If the voltage is too low, this alarm occurs.

Troubleshooting:

Please check:

- The motor connected to -P must be completely still before this alarm occurs. The software waits 30 seconds before showing this alarm. During this time it shows the WAIT MOTOR STILL warning.
- Motor internal connections
- Motor power cables connections
- Motor leakage to truck frame
- If the motor connections are ok, the problem is inside the controller it is necessary to replace the logic board.

PUMP I NO ZERO *(MDI/LED code = 56)*

Cause:

In standby condition (pump motor not driven), the feedback coming from the current sensor in the pump chopper gives a value out of a permitted range, because the pump current is not zero.

Troubleshooting:

This type of fault is not related to external components; replace the controller.

PUMP I=0 EVER *(MDI/LED code = 52)*

Cause:

While the pump motor is running, the current feedback is constantly stuck to zero.

Troubleshooting:

- Check the motor connection, that there is continuity. If the motor connection is opened, the current cannot flow, so the test fails and the error code is displayed;
- If everything is ok for what it concerns the motor, the problem could be in the current sensor or in the related circuit.

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.

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.

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 (A1): 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.

SMARTDRIVER KO *(MDI/LED code = 69)*

Cause:

There is a hardware problem in the smart driver circuit (high-side driver on pin A2). The driver is set to be ON but the output voltage does not increase.

Troubleshooting:

- Verify that the EB coil is connected correctly between pin A2 and pin A4.
- Verify that the parameter POSITIVE E.B.is set in accordance with the actual configuration (see paragraph 8.2.5). The software, in fact, depending on specific parameter value, makes a proper diagnosis; a wrong configuration of this parameter could generate a false fault.
- In case no failures/problems have been found, the problem is in the controller, which has to be replaced.

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 ERROR *(MDI/LED code = 64)*
Cause:
Input mismatch between the Hard&Soft input (A6) and the TILLER/SEAT input (A1): the two inputs are activated at the same time.

Troubleshooting:
- Check if there are wrong connections in the external wiring.
- Using the TESTER menu of the controller verify that what the controller sees in input is in accordance with the actual state of the external switch inputs.
- Check if there is a short circuit between A6 and A1.
- In case no failures/problems have been found, the problem is in the controller, which has to be replaced.

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 9.1).
- The acquired values MIN VACC and MAX VACC are inconsistent.

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

VDC LINK OVERV. *(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.

VDC OFF SHORTED *(MDI/LED code = 88)*

Cause
The logic board measures a voltage value across the DC-link that is constantly out of range, above the maximum allowed value.

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

VKEY OFF SHORTED *(MDI/LED code = 20)*

Cause

At key-on, the logic board measures a voltage value of the KEY input that is constantly out of range, below the minimum allowed value.

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

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 controllers for brushless motors.

WAIT MOT.P STILL *(MDI/LED code = 45)*

Cause:
If DC Pump option is set to ON, the software expects the voltage on -P output to be at a “steady state” value, before switching the LC on.
If the voltage is different, it could be due to the fact that the motor connected to -P is not still. For this reason, the software waits 30 seconds for the voltage to be at the “steady state” value (and for the pump motor to be still). After this time, the software assumes that the problem is not due to the fact that the pump motor is not still, and show the PUMP VMN NOT OK alarm.

Troubleshooting:
- If the motor connected to -P is still moving, just wait for it to be still.
- If not, in 30 seconds the alarm PUMP VMN NOT OK will appear.

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 parameters ENCODER PULSES 1 and ENCODER PULSES 2 (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 the KEY input A10) 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 A10. 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.

10.4 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
SP MISMATCH PUMP	MC is opened, EB is applied, traction/pump stopped	Running	Key re-cycle	18	FFF1	241
OUT MISMATCH PU	MC is opened, EB is applied, traction/pump stopped	Running	Key re-cycle	20	FFF0	240
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

10.4.1 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 the controller 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 the 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.

OUT MISMATCH PU *(MDI/LED code = 20)*

Cause:

This is a safety related test. Supervisor µC has detected that master µC is driving the pump motor in a wrong way (not corresponding to the operator request).

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 supervisor µC has detected a mismatch in the speed setpoint with respect to the master µC. 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.

SP MISMATCH PUMP *(MDI/LED code = 18)*

Cause:

This is a safety related test. The supervisor µC has detected a mismatch in the DC-pump speed setpoint with respect to the master µC.

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.

10.5 Info code for electrovalves

Errors related to HW circuits driving electrovalves (CONT DRV. EV, DRV. SHOR. EV) are followed by an info code which helps to detect which EV circuit is affected by the problem.

EVs are coded with a hexadecimal number:

- **02:** EV1 (A9)
- **04:** EV2 (A11)
- **08:** EV3 (A33)
- **20:** EV4 (A34)
- **80:** EV5 (A8)

If more than one EV circuit is found to be faulty, the code shown corresponds to the sum of the single info codes. This results in the following table of possibilities, where faulty EVs are marked with an “F”.

Info code	EV1	EV2	EV3	EV4	EV5
02	F				
04		F			
06	F	F			
08			F		
0A	F		F		
0C		F	F		
0E	F	F	F		
20				F	
22	F			F	
24		F		F	
26	F	F		F	
28			F	F	
2A	F		F	F	
2C		F	F	F	
2E	F	F	F	F	

Info code	EV1	EV2	EV3	EV4	EV5
80					F
82	F				F
84		F			F
86	F	F			F
88			F		F
8A	F		F		F
8C		F	F		F
8E	F	F	F		F
A0				F	F
A2	F			F	F
A4		F		F	F
A6	F	F		F	F
A8			F	F	F
AA	F		F	F	F
AC		F	F	F	F
AE	F	F	F	F	F

11 SPARE PARTS

Part number	Description
C12532	AMPSEAL CONNECTOR 35 pins Female
C29508	SW 180 24V Single Pole Contactor
C29522	SW 180 48V Single Pole Contactor

12 PERIODIC MAINTENANCE

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

Check the Foot pedal or Tiller microswitch. Using a suitable test meter, confirm that there is no electrical resistance between the contacts by measuring the voltage drop between the terminals. Switches should operate with a clear click sound.
Microswitches should be checked every **3 months**.

Check the Battery cables, cables connected to the inverter, and cables connected to the motor. Ensure that the insulation is sound and that the connections are tight.
Cables should be checked every **3 months**.

Check the mechanical functionality of the pedals or tiller. Control that the return springs are ok and that the potentiometers excursion matches their full or programmed level.
Check every **3 months**.

Check the mechanical functionality 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 of NON ORIGINAL PARTS.
The installation of this electronic controller should be made according to the diagrams included in this Manual. Any variations or special modifications should be evaluated with a Zapi Agent. The supplier is not responsible for any problem that arises from connections 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 brought to the attention of a Zapi Agent immediately. The Agent will then take the decision regarding the 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 kinds of waste materials.
Zapi commits itself to update its technology in order to reduce the presence of polluting substances in its products.

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13 APPENDICES

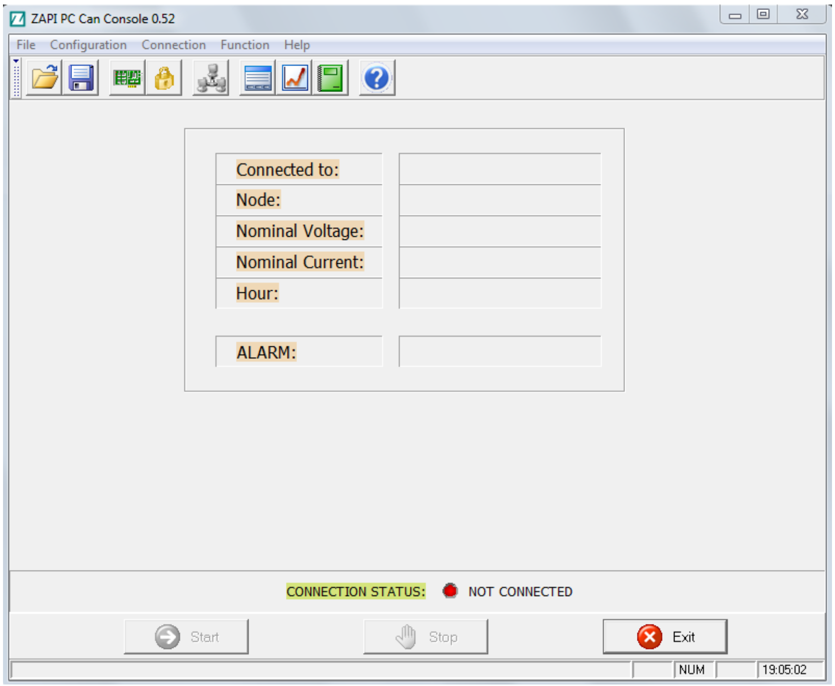
The goal of this chapter is to give to the operator a general overview relating the use of Zapi PC CAN Console and Zapi Smart Console.
The description contained in the next paragraph focuses on the basic information about the connection and change of parameters.
For additional functionalities available 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

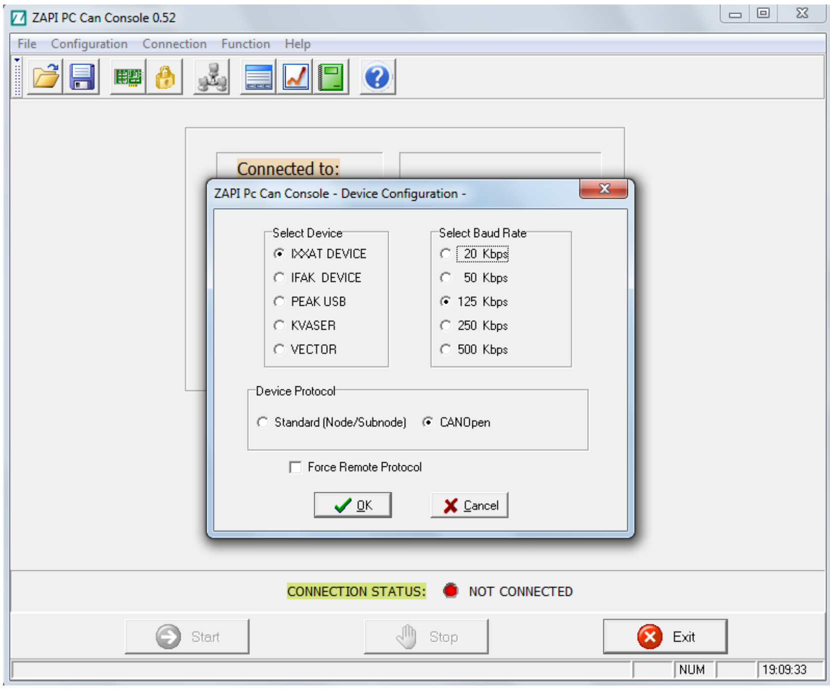
Windows Pc CAN Console uses standard Zapi communication protocol to display inverter's information. It provides all standard Zapi Console functions with the easier handling of Windows devices. Besides, Pc CAN Console offers another function: the possibility to save parameter configurations to a file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

13.1.1 PC CAN Console configuration

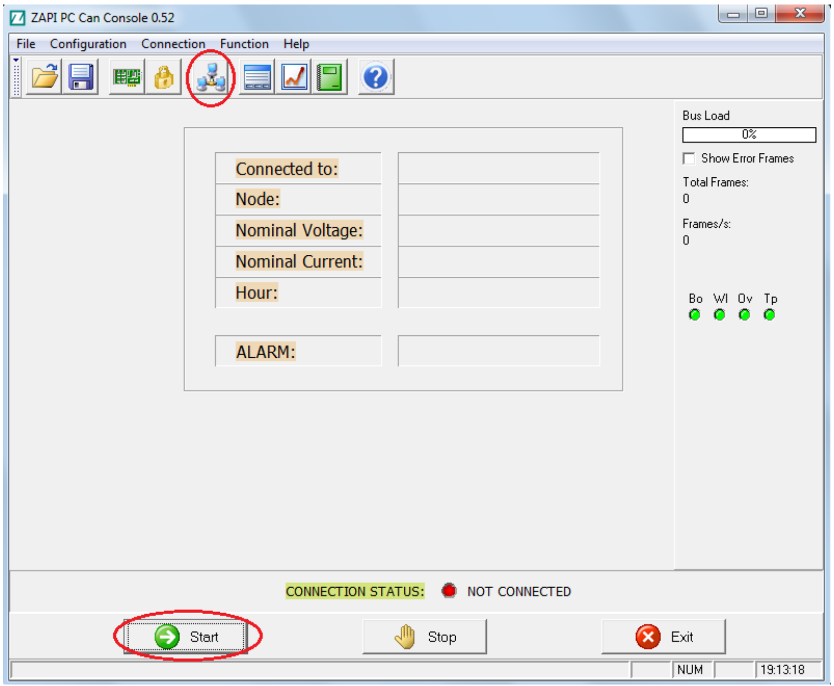
Running the PC Can Console software, the following window will appear:



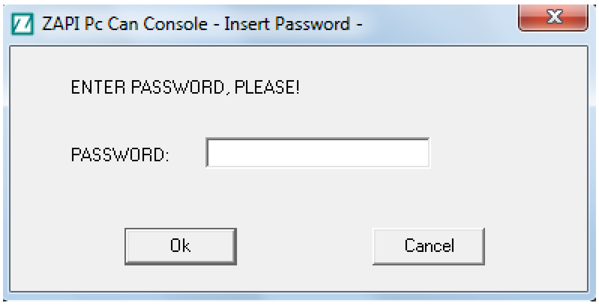
the first step to accomplish is to define the CAN device attached to the PC, so select the "Configuration" (Alt-C) -> Can Device (Ctrl-C) menu or click on Can Device icon.



From this form you can define the CAN-device used (IXXAT or IFAK or Peak) and the CAN communication speed then press the OK button.
Once you have defined the CAN interface, you have to choose which CAN-device you need to connect to, then choose “Connection” -> “Set Node” menu (or push the “Set Node” icon).



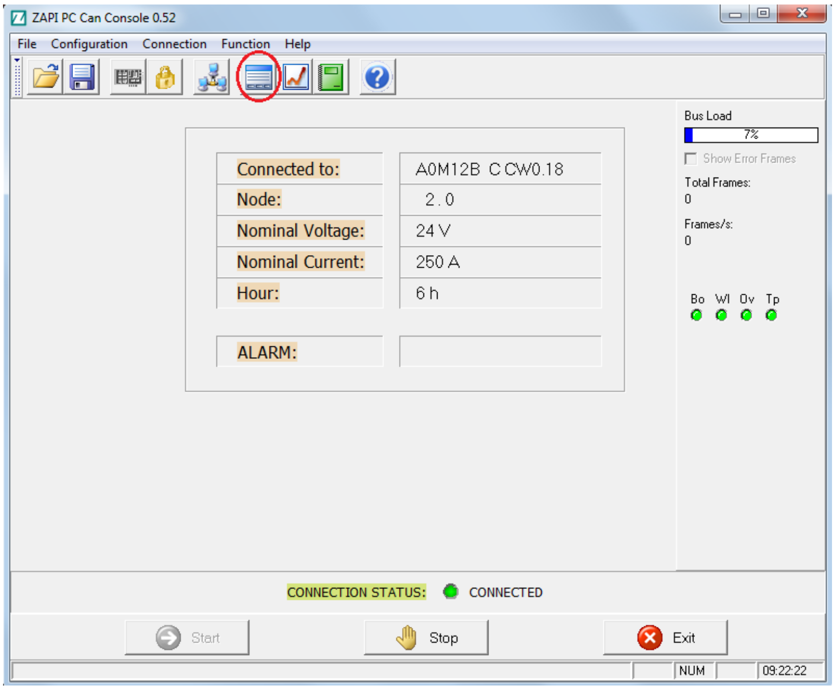
Once you have chosen the node to which you want to connect, start the connection and insert the password in order to have the possibility to change the parameters.
So, choose “Configuration” -> “Enter Password”.



Write the Password -> “ZAPI”

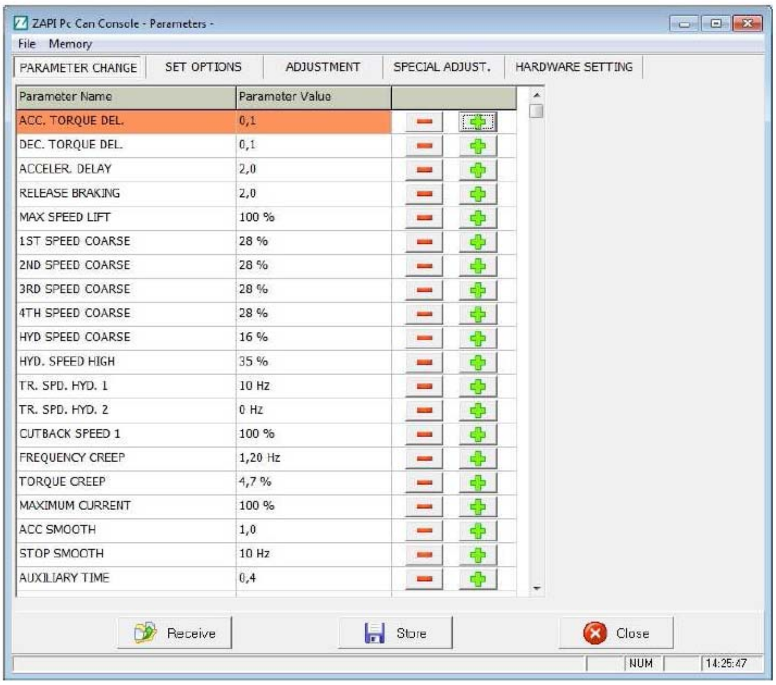
13.1.2 Parameter download

Once you are connected to the selected node, you need to download the inverter’s parameters; choose “Function” > “Parameter” menu (or push the “Parameter” icon).



Then click on Receive button: the parameters will be downloaded automatically. When the device has finished to send the device parameters you can change them.

13.1.3 How to modify the parameters



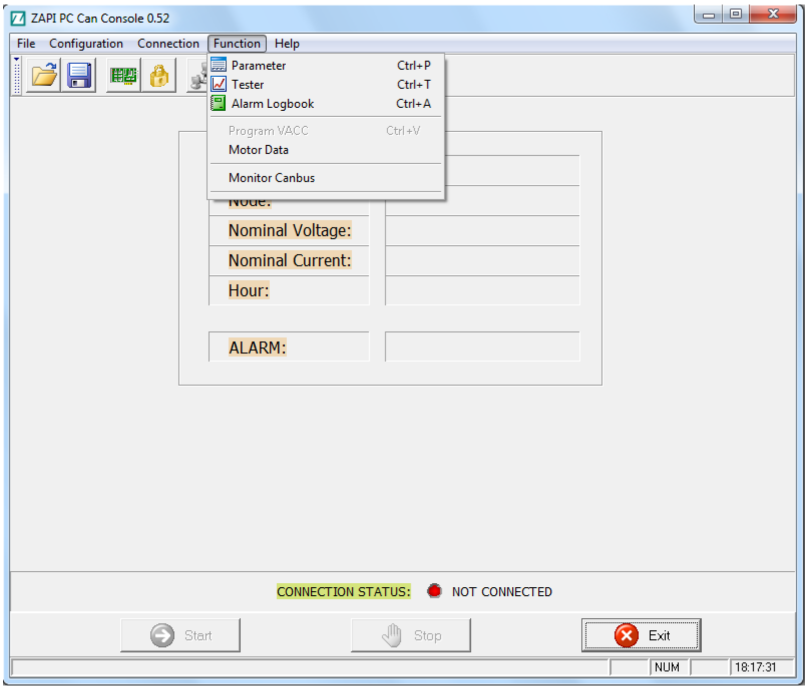
Before doing any change, save the old parameters set by clicking over “File” > “Save” and give to the file an understandable name.
The complete list of parameters will be saved as a .csv file in order to be opened with Microsoft Excel® or any other spreadsheet generator tool.
The file contains the whole list of parameter and, for each parameter, various kinds of information are available, in particular:

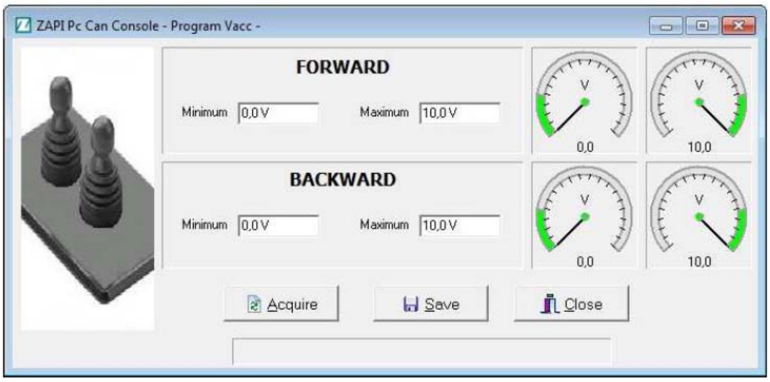
- Parameter value as it is saved within controller (“Value” column)
- Parameter value as it is shown by console or similar tools (“Scaled Value” column)
- Name of the menu where parameter is placed (“Name menu” column)

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





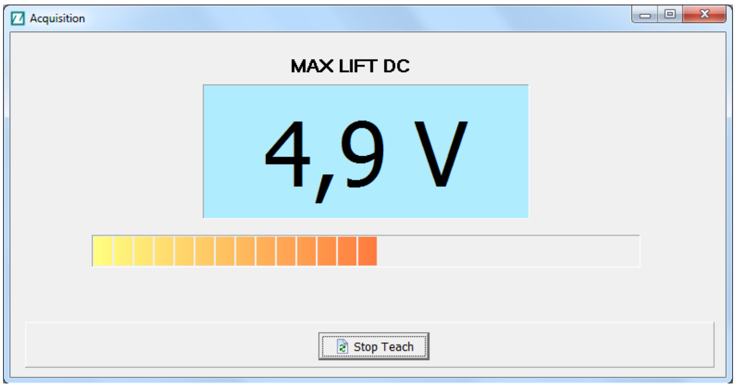
When “Acquire” is pressed, the PROGRAM VACC procedure will start:

- Select the Enable switch, if any;
- Select the direction switch (either forward or backward);
- Press the pedal up to its maximum excursion.

Displayed values will vary accordingly to operator inputs.

13.1.5 Lift & Lower command acquiring

Once you are connected to the inverter, you need to download the parameters; choose “Function” > “Parameter” menu (or push the “Parameter” icon).
Choose “Adjustment” menu.
Select the value you want to acquire by pressing the “acquiring” button and 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.

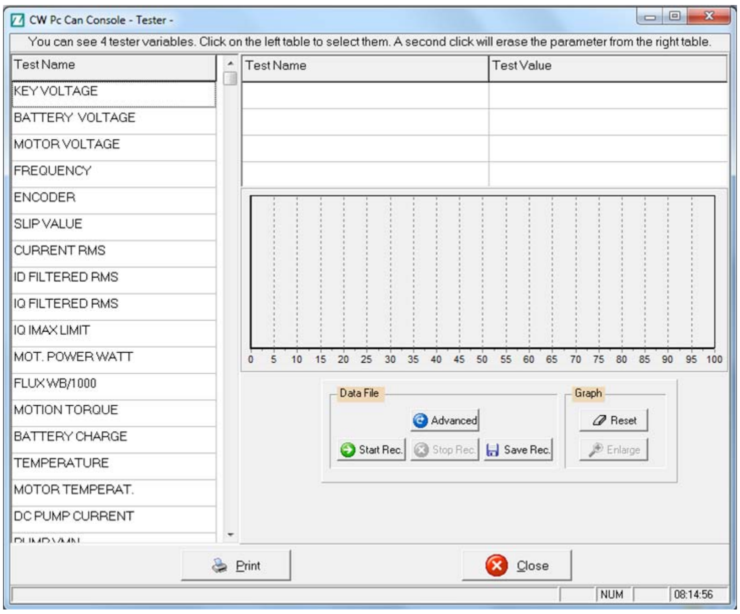
The procedure is the same for all the lift and lower potentiometers.

13.1.6 Steer acquiring

Once you are connected you need to receive the inverter’s parameter; choose “Function” > “Parameter” menu (or push the “Parameter” icon).
Choose “Adjustment” menu.
Select the value to acquire by pressing “acquiring” button and the acquisition will start: the procedure is the same described for Lift & Lower acquisition at paragraph 13.1.5

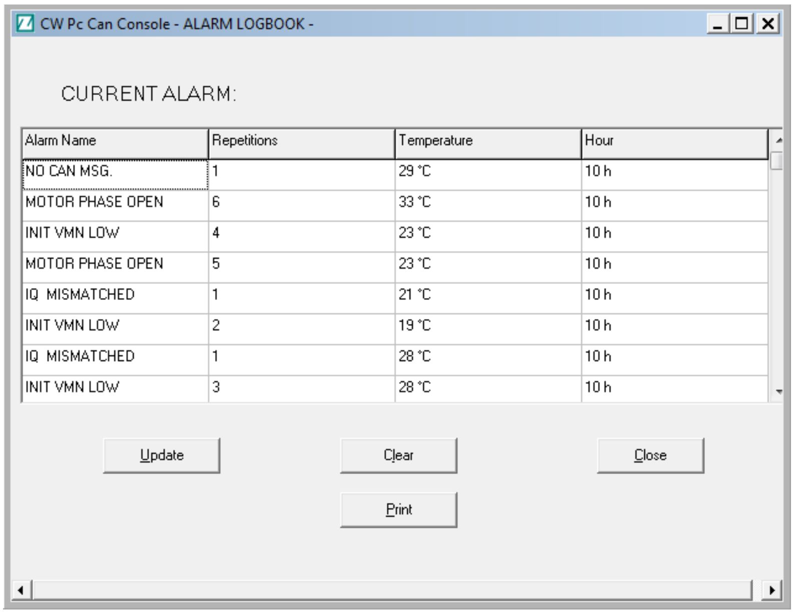
13.1.7 Tester Functionality

From the main page you can also access to the inverter TESTER menu 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 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

The 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

The Smart Console offers the same serial connection as the well-known Console Ultra.

Main characteristics of this operational mode are:

- Current-loop serial communication;
- Console is connected to a *single* controller only (even if Remote Console option is available);
- Baud-rate selectable;
- 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 characteristics of this operational mode:

- It can be connected to a CAN line composed of any combination of modules, both Zapi ones and not-Zapi ones;
- Supported speeds: 125 kbps, 250 kbps, 500 kbps;
- It sees the entire CAN line and all CAN modules.

13.2.2 The keyboard

The keyboard is used to navigate inside the different 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 “scroll”.

LEFT and RIGHT keys
Normally used to increase and decrease the value associated with the selected item inside a menu.

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.

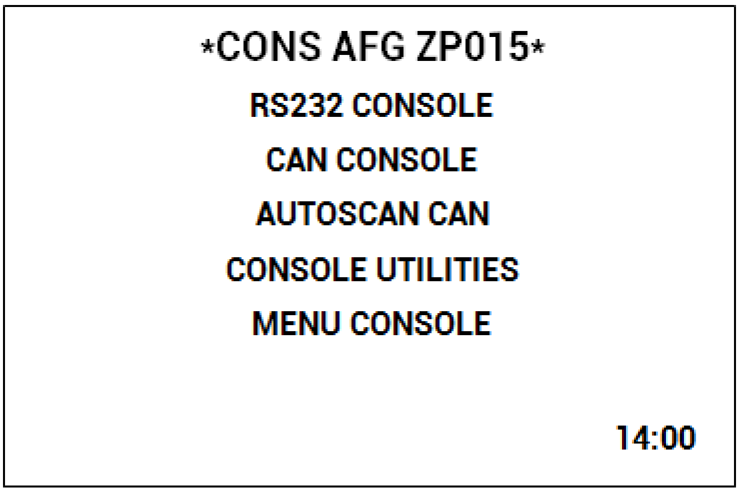
F1, F2, F3 keys
These buttons have a contextual use. The display will say which F button can be used and its function.

ON key
Used while operating with internal batteries.

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

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

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



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 must be turned on and still.

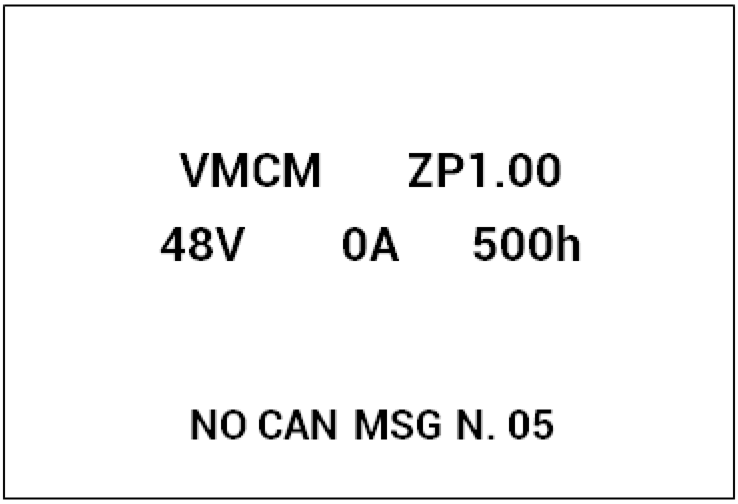
The “RS232” line is already highlighted at the start-up so press OK key to start a serial connection.
Display prompts a message to inform you that a connection attempt is ongoing.

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 an image similar to the next one.



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 pressing many buttons all at once: now 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 a parameter

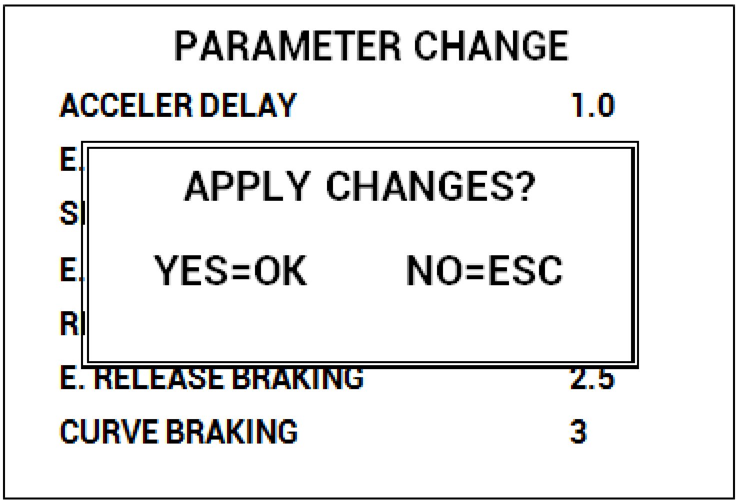
From MAIN MENU enter the menu inside that there is the parameter that you want to change (for example the PARAMETER CHANGE menu).

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 whole list: once you have highlighted the parameter that you want to modify, use LEFT or RIGHT keys to decrease or increase the parameter value.

Keep 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.

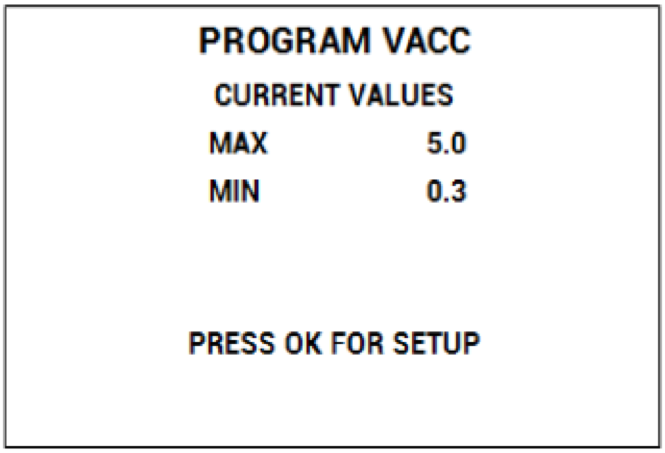
You can press ESC to exit the menu at any time. In case some parameter has been modified, the console will prompt a request to confirm/discard changes.



Description above is valid for every menu which contains parameters and options like SET OPTIONS, ADJUSTMENTS, HARDWARE SETTINGS, etc. .

13.2.6 Program VACC

Program VACC menu has been slightly modified compared with old console. Upon entering this menu the console will show the current programmed values.



When OK is pressed PROGRAM VACC procedure will start: console will invite you:

- To select the Enable switch, if any;
- Then select the direction switch (either forward or backward);
- Press the pedal up to its maximum excursion.

Displayed values will vary accordingly to operator inputs.

Sequence above can slightly vary depending on controller firmware. Anyway the logic will remain the same: before programming the min/max values, execute any starting sequence which is necessary, then press the pedal/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 will ask if programmed values must be saved or discarded.

13.2.7 Lift and Lower commands acquiring

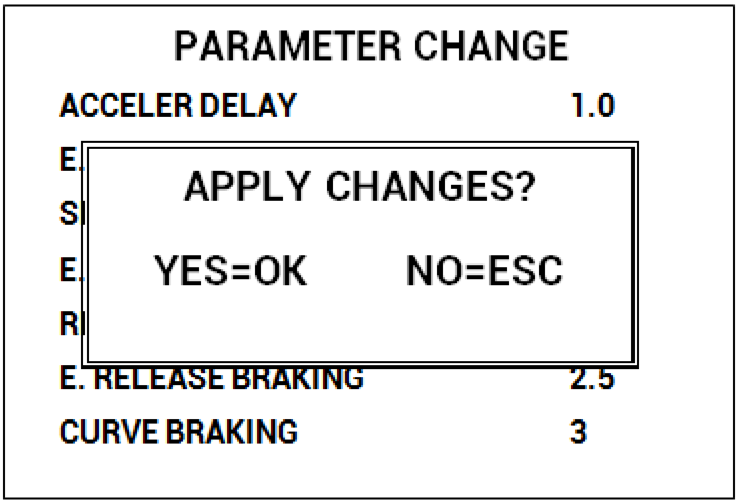
From MAIN MENU enter the Adjustment menu.
With UP and DOWN keys you can scroll the whole list: once you have highlighted a value that you want acquire press OK.
When OK is pressed the procedure will start:

- 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 will vary accordingly to operator inputs.

Sequence above can slightly vary depending on controller firmware. Anyway the logic will remain the same: before programming the min/max values, execute any starting sequence which is necessary, then press the pedal/push the joystick.

It is possible step by step 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.

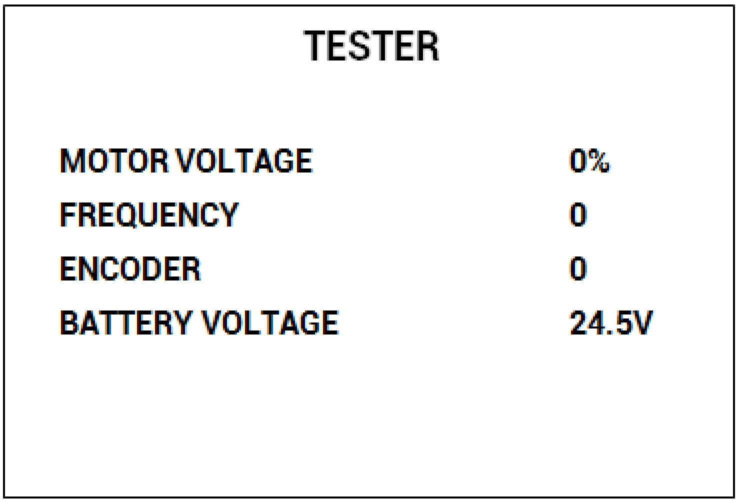


13.2.8 Steer command acquiring

From MAIN MENU enter the Adjustment menu.
The procedure to follow is the same described in paragraph 13.2.7.

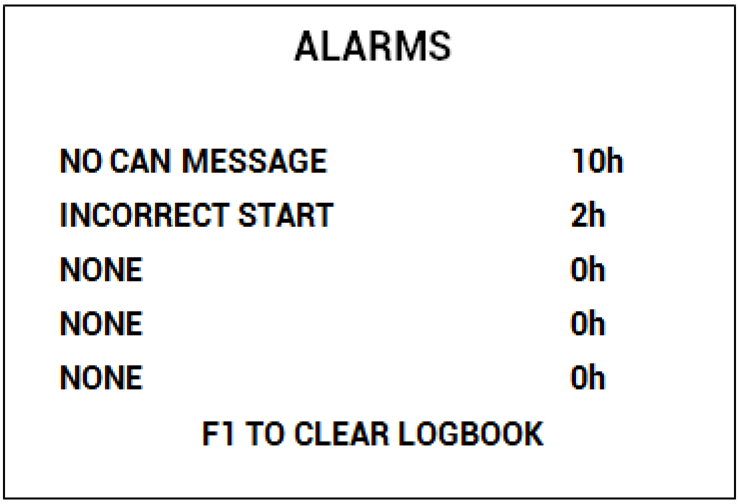
13.2.9 Tester

Compared to standard console Ultra, the TESTER menu has been modified deeply. Now it shows four variables at once: use UP/DOWN keys to scroll the list as usual.



13.2.10 Alarms

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



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 information about that alarm will be displayed.

Press F1 to cancel the alarm logbook of the controller: once pressed, the console will ask for confirmation.

13.2.11 Download parameter list to USB stick

When Smart Console is connected to a controller, it has the possibility to download all parameters inside a USB stick.
To use this function, enter the menu SAVE PARAMETER USB in the MAIN MENU.

File format

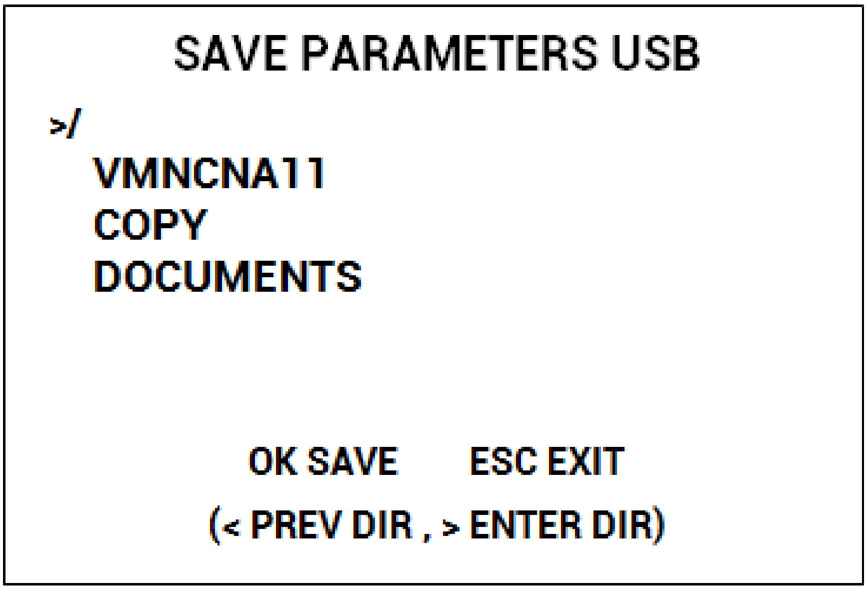
The complete list of parameters is saved as a .csv file in order to be opened with Microsoft Excel® or any other spreadsheet generator tool.
The file is formatted in the same way as if it has been created with the PC CAN Console. Thus it contains the whole list of parameter and, for each parameter, various kinds of information 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 a 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 will check the presence of the USB stick. If the stick is not connected yet, it will ask the operator to connect one.
When the stick is present, the display will show the content, starting from the root directory (/) of the filesystem. It should look like the following picture.



Notice that only directories are shown, not single files.
While exploring the content, the navigation buttons work in the following way:

- Up/down keys are used to control scrolling.
- Right key enters the highlighted directory: its content (directories only) will be shown immediately.
- Left key returns up to one level in the directory structure: it does not work while being in /
- 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, use following procedure:

1. Navigate the directory list and enter 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

3. Press OK to start parameter download. A progression bar shows the process.
4. When finished, press ESC and display will return to MAIN MENU. USB stick can be removed safely

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

During download the LED will blink slowly to indicate the console is still running. When download has finished USB stick can be unplugged safely.

Do not remove USB stick during download or the file will be empty or corrupted!
