



**ZAPI**® S.p.A.

**ELECTRONIC • OLEODYNAMIC • INDUSTRIAL  
EQUIPMENTS CONSTRUCTION**

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*User Manual*

# EPS-AC0



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### APPROVAL SIGNS

COMPANY FUNCTION	INIZIALS	SIGNS
PROJECT MANAGER	MI	
TECHNICAL ELECTRONIC MANAGER VISA	PP	
SALES MANAGER VISA	PN	

Publication N°: **AEMZP0BA**  
Edition: **May 2006**

# 1 INTRODUCTION

This equipment (Eps-ac0: AC0 Electrical Power Steering) may perform two steer by wire functions on a truck:

- 1) manually controlled power steering
- 2) automatic centering (AUTC).

Manually controlled steering may use either a stepper motor (used as a tachogenerator) or a twin pot fixed to the steering wheel.

Feedback sensors are mandatory to close the loop when an automatic function is required (Automatic Centering).

Feedback sensors are mandatory to close the loop in manual mode if a twin pot is mounted on the steering wheel.

Feedback sensors are strongly suggested (to improve safety) in manual mode if a stepper motor is mounted on the steering wheel (open loop).

The feedback sensor may be an incremental encoder on the steering motor shaft in combination with one straight-ahead switch. A second switch may be adopted, together with the first one, in the 90 degrees position to improve safety. Besides a feedback potentiometer may be chosen in alternative to the straight-ahead switch.

**The eps-ac0 runs an inexpensive, robust and maintenance free three phases AC induction motor.** Also, our patented system makes possible **to use a very low-resolution encoder (4 pulses/rev are more than enough)** mounted on the steering motor shaft.

**The on board CAN interface** makes the communication exchange between our eps-ac0 and other units in the truck rapid and simple. Via CAN it is possible to enhance the steering performances with additional functions like: steer sensitivity changes with the traction speed, traction speed modulation vs. the steered angle, via CAN automatic centering request and so on.

**Configuration options, steering adjustment, measurement functions, and troubleshooting operations are integrally supported by the ZAPI hand held controller** equipped with Eprom release number CKULTRA ZP3.01 or subsequent. Having two microprocessors provides improved safety and operation. The first microprocessor performs operations and a second one executes supervisor functions. **Both the aboard microprocessors are CAN BUS connected, as consequence the eps-ac0 may receive a remote steering command directly via CAN fulfilling the norm (the redundant check of the steering command complies with the Category #3 requirement).**

The microprocessors combined with the ZAPI hand held controller make servicing easy and direct, reducing adjustment and troubleshooting time. Increased steering motor performance and reduced noise levels are achieved by using MOSFET technology.

The reference SW release for this manual is ZP0.70.

# 2 SPECIFICATION

## 2.1 Technical specifications

- Steering controller for AC asynchronous 3-phase motors
- Digital Control using Two Microprocessors
- Can-Bus interface
- Both microprocessors Can Bus connected
- Encoder Interface
- Stepper Motor or Twin Pot Interface
- Analog Feedback pot interface (1024 steps resolution)
- Analog KTY84-130 thermal sensor input
- Analog input with 1024 steps resolution (one input)
- Analog input with 4096 steps resolution (one input)
- Two digital inputs
- Double Safety Relay inside
- Operating frequency: ..... 8 kHz with center aligned PWM
- External temperature range: ..... -30 °C ÷ 40 °C
- Maximum inverter temperature: ..... 75 °C
- Environment protection: ..... IP54

## 2.2 Block diagram

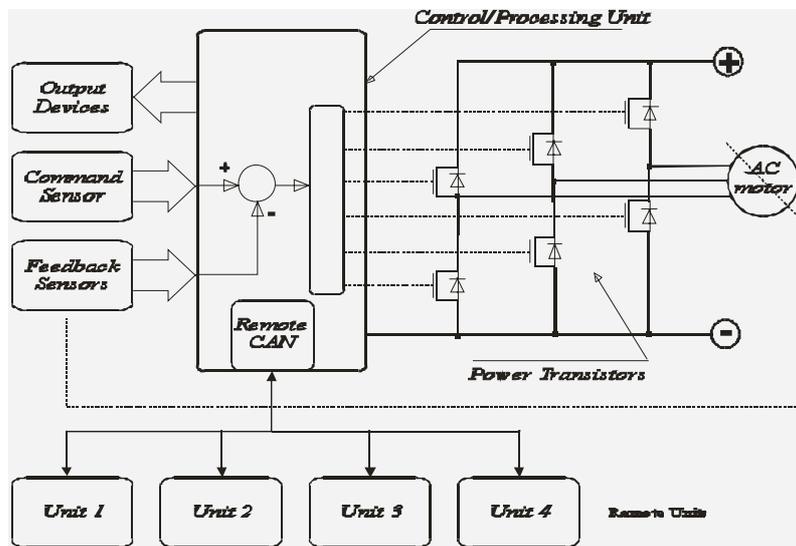


Figure 2-1

## 2.3 Electrical specifications

- Battery Voltage: ..... 24 V-36 V
- Maximum current (24 V-36 V): ..... 50 A (RMS) for 2'
- Logic Supply current: ..... max 200 mA @ 24 V

Minimum Input (key) Supply Voltage after start-up:.....12 V

## 2.4 Mechanical specifications

### 2.4.1 Basic release

It has Molex Minifit connector with international protection IP54.

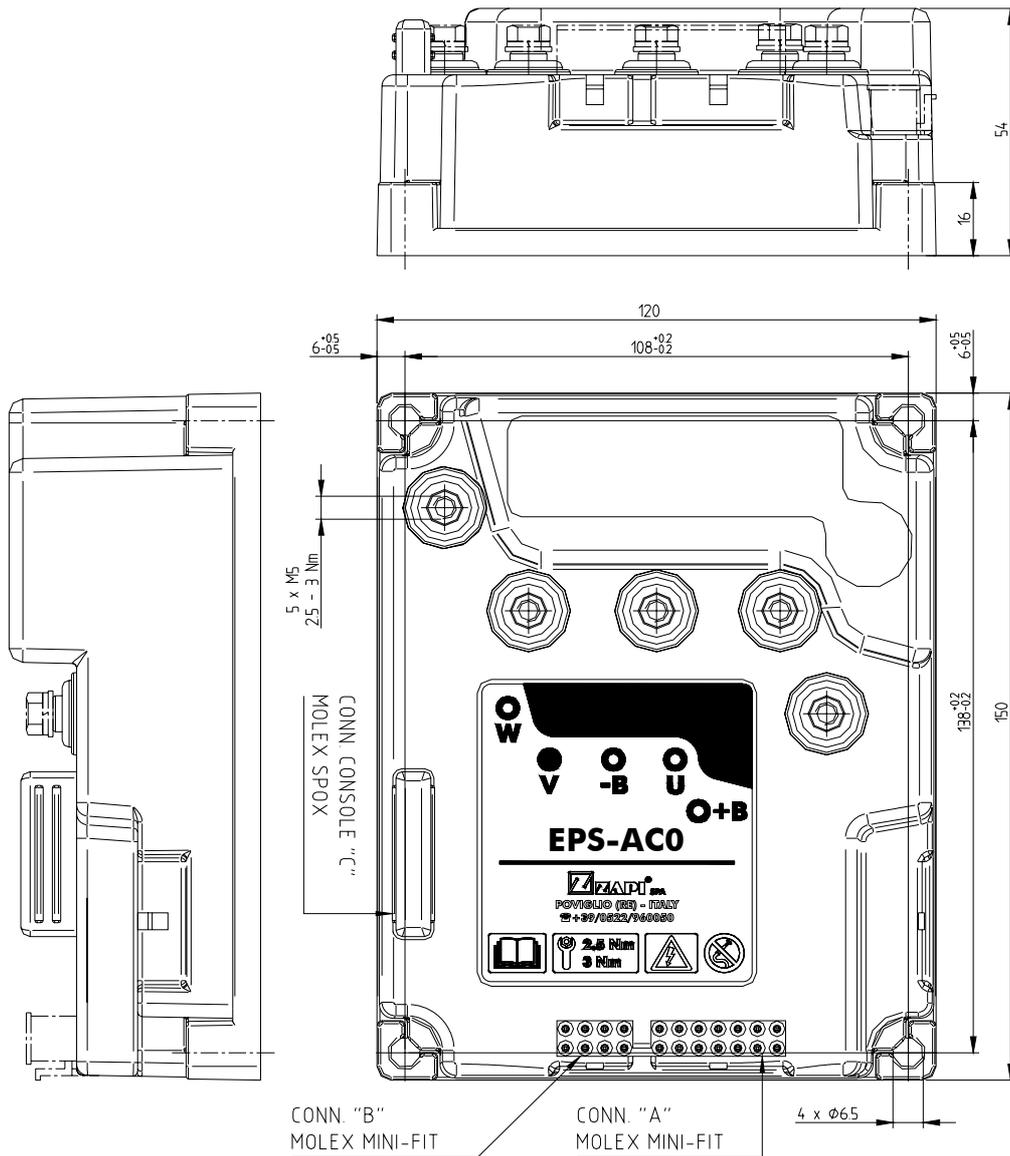


Figure 2-2

# 3 FUNCTIONS OF THE EPS-AC0

The eps-ac0 controls a steer system for warehouse trucks. It executes the following functions:

- 1) Manual mode steering
- 2) Automatic Centering.

## 3.1 Manual Mode Steering

Manual mode steering requires a command sensor in the hand wheel. The hand wheel may be of two types:

- 1) Multiturn steering wheel without end-strokes.
- 2) Handlebar, tiller or joy-stick with end-strokes to limit the angle.

With a Multiturn steering wheel, the sensor in the hand-wheel shall be a stepper motor used as a tacho-generator (see Figure 3-1). Then the control will turn the steering motor moving at a speed proportional to the stepper motor speed (Open loop Mode).

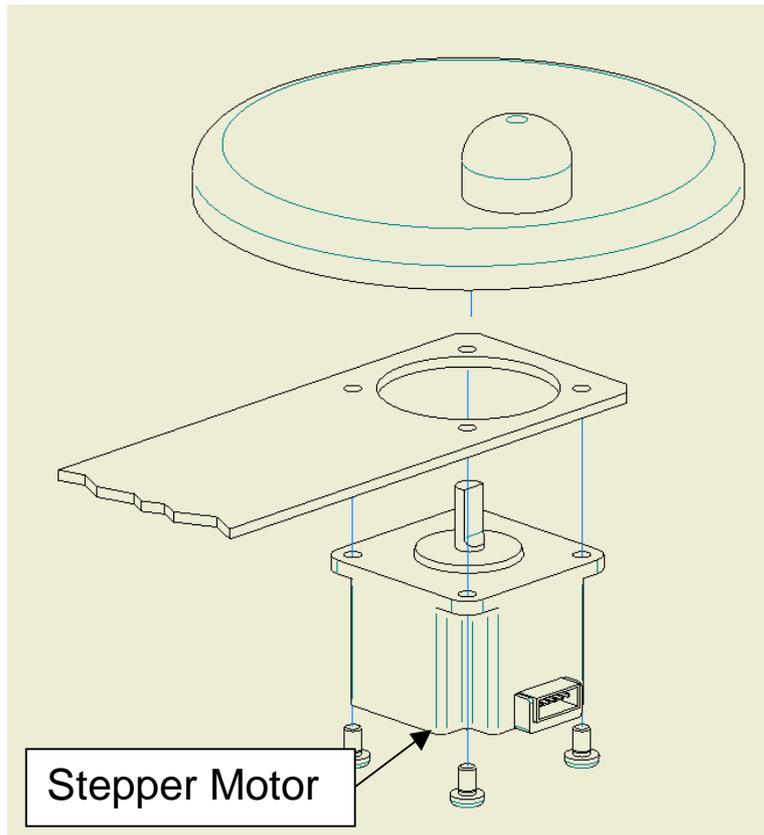


Figure 3-1

With a Handlebar (tiller or joy-stick), the sensor in the hand-wheel will be a twin pot (see Figure 3-2 below). Then the system works as a position control loop with a rigid correspondence between the angle of the handlebar and the angle of the steered wheel (Closed Loop Mode). In this case a feedback sensor on the steered wheel is mandatory.

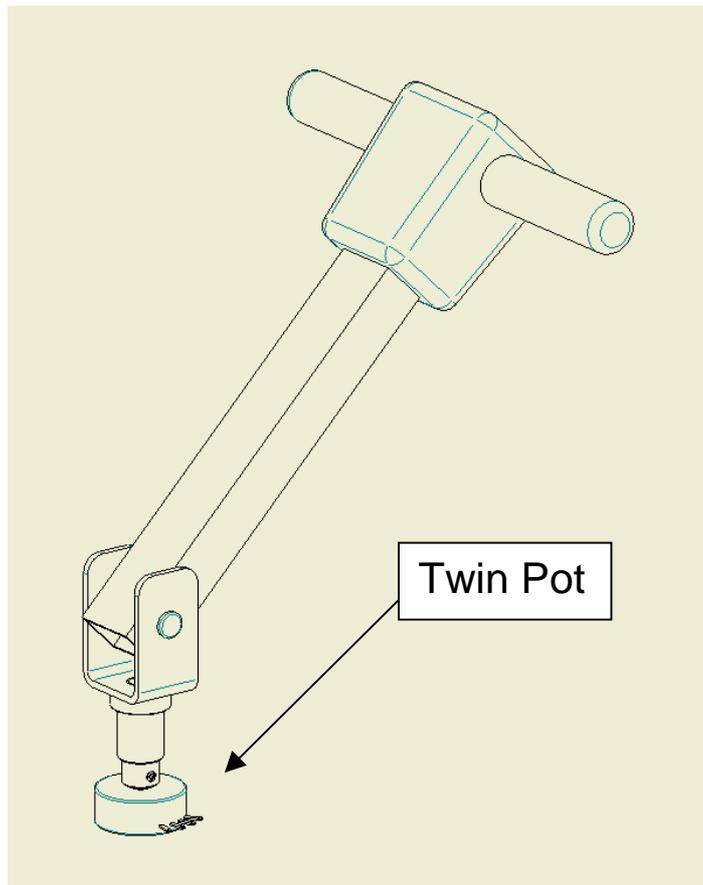


Figure 3-2

The same controller may work either with the stepper motor or the twin pot without hardware modification. It is just enough to set the SYSTEM CONFIG to the correct value (see 12.4.3.1).

### 3.2 Automatic Centering

Automatic Centering turns the steered wheel straight ahead to keep the steer aligned meanwhile travelling inside an aisle between rails (see Figure 3-3).

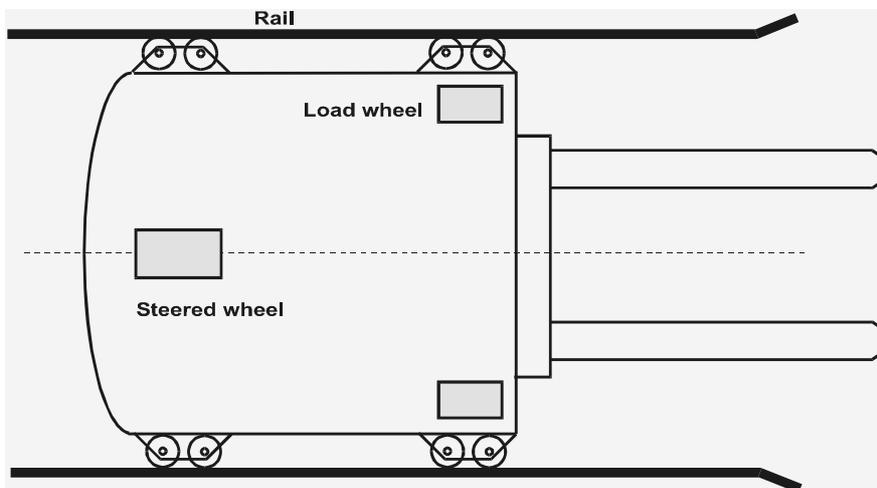


Figure 3-3

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### 3.3 Operational features

A list of eps-ac0 operational features follows below:

- 1) Static sensitivity boost in open loop (steering sensitivity increases for a slow moving steering wheel).
- 2) Static numbness in closed loop (steering sensitivity decreases for handle steer close to the straight-ahead direction).
- 3) Dynamic Numbness in open loop (steering sensitivity reduces when the truck speed increases).
- 4) Dynamic Numbness on request in closed loop (steering sensitivity reduces when the truck speed increases).
- 5) Truck speed reduces when the steering angle increases.
- 6) Alignment at the rest position in open loop application (to avoid the drift of the steered wheel when travelling with released steering wheel).
- 7) Embedded PID algorithm for closed loop application (Twin Pot).
- 8) Embedded PID algorithm for automatic functions (AUTC).
- 9) Special Debugging & Troubleshooting system makes easier the fault catching.
- 10) Possibility to run in a stand-alone (not CAN Bus supported) configuration.
- 11) Motor control may be performed with or without encoder. Default choice is without encoder. The adoption of a cheap and low-resolution encoder is possible.
- 12) Redundant processing (two microprocessors aboard) fulfils the Category #3 requirement including the set-point comes via CAN Bus from a remote unit.
- 13) Redundant set point and feedback sensors fulfil the Category #3 requirement.
- 14) Redundant safety-contact fulfils the Category #3 requirement in a stand-alone configuration.

---

### 3.4 Diagnosis

According to EN1175, most of the diagnoses deenergize steer and traction in less than 100 msec. Few secondary alarm conditions require longer time for detection. They too deenergize steer and traction: it is better to have delayed alarm than no alarm at all.

Diagnosis is provided in two ways. The digital console can be used, which gives a detailed information about the failure; the failure code is also sent on the Can-Bus.

# 4 SYSTEM COMPONENTS

The eps-ac0 controller needs some external parts in order to work. The following list describes the complete equipment.

---

## 4.1 Steering Motor

The steering system includes a three phase AC induction motor. The motor rated power (S2-1h) changes with the truck type. As a thumb rule:

- 1) A low level OP asks a motor with rated power higher than 250 W @ 3000 rpm.
- 2) A reach truck asks a motor with rated power higher than 400 W @ 3000 rpm.

Obviously the above list is only a rough information: the motor should be chosen from time to time according the rated torque and speed customer's specifications.

---

## 4.2 Gear Box and total reduction ratio

Normally, the total reduction ratio between steered wheel and motor shaft should be close to 1:200. Normally it is split into:

- 1) Gear box ratio close to 1:50.
- 2) External gears ratio close to 1:4.

The maximum continuous output torque requirement changes with the truck type. As a thumb rule and in the worst case (stalled steer):

- 1) A low level OP asks a maximum torque of about 250 Nm on the wheel to steer.
- 2) A reach truck asks a maximum torque of about 600 Nm on the wheel to steer.

Obviously the above list is only a rough information: the reduction ratio together with the gear-box should be chosen from time to time according the customer's specifications.

---

## 4.3 Eps-ac0 controller

It consists of a control unit on a PCB marked AEMZPA0B (see Figure 4.1) which operates the AC asynchronous motor for manual and centering mode. Eps-ac0 works with 24 to 36 V battery and a maximum current up to 50 Aac.

It has flash memory aboard and it is possible to boot the SW in the Master microprocessor through both, Serial hand set connector (CNC) and via CAN Bus. For the Slave microprocessor, only via CAN Bus booting is admitted. A Zapi own program (Flasher) is needed to boot-on the SW.

### 4.3.1 Eps-ac0 PCB

It has Molex Minifit connector with international protection IP54.

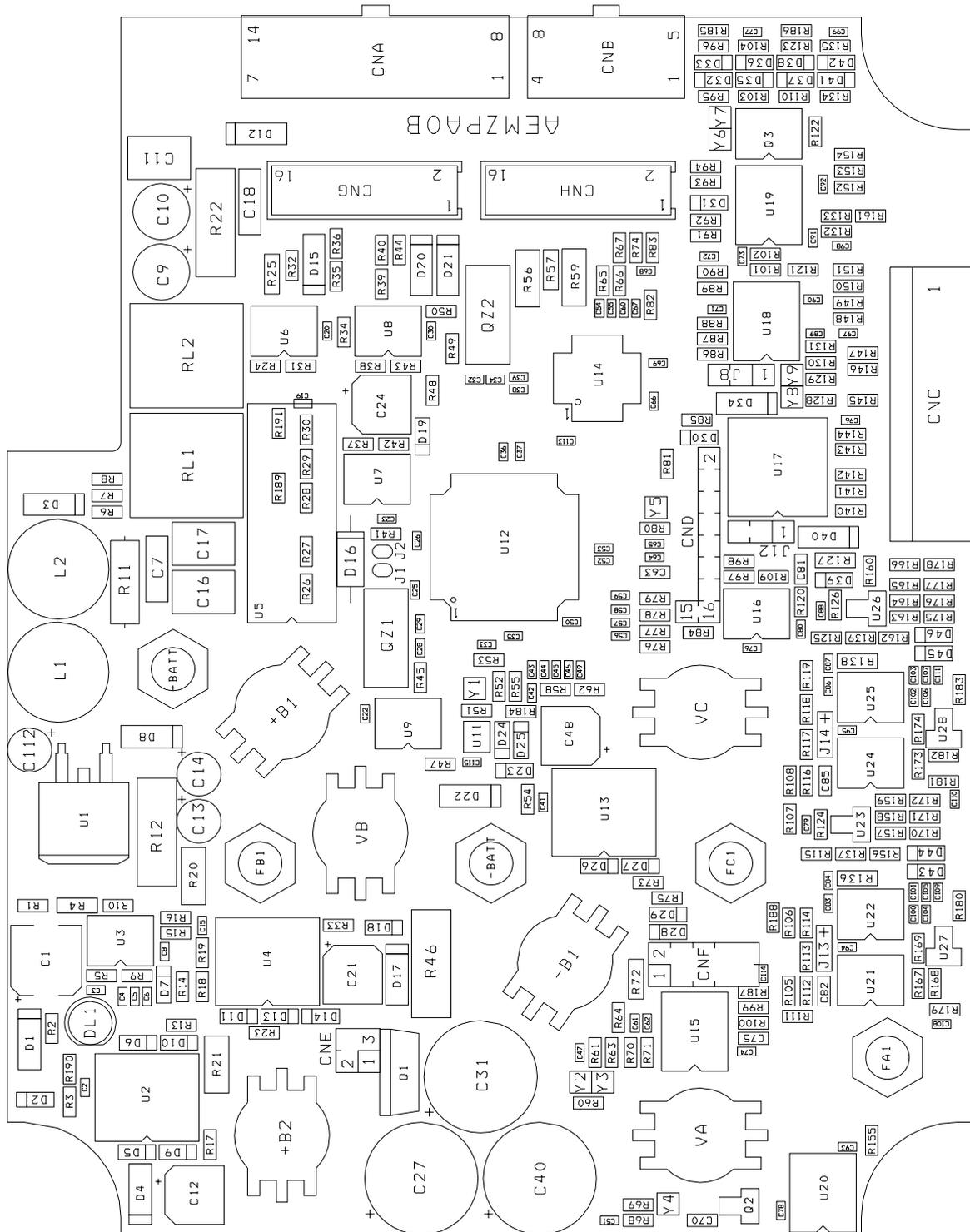


Figure 4-1

## 4.4 Sensor in the steering handle

Two configurations are foreseen:

- 1) No limit, multiturn steering wheel.
- 2) Tiller, handlebar or joystick arrangement with a limited angle.

Depending by the above choice, there are two different handling:

- 1) In case of multiturn steering wheel, a stepper motor is used.
- 2) In case of a handlebar with limited angle, a twin pot is used.

### 4.4.1 Stepper motor

The stepper motor is used as a tachogenerator. The following part numbers resulted suited to work with eps-ac0:

- 1) MINEBEA Type code AA23KM-K227-T20V.
  - 2) JAPAN SERVO Type Code KH56JM2X 1269 DC12V 30 ohm.
- They have the same mechanical dimensions (see Figure 4.2 below).

Obviously, the above information states only these parts are suited for the eps-ac0; no reliability evaluation is given here.

Other sources are possible on request, but must be tested for approval.

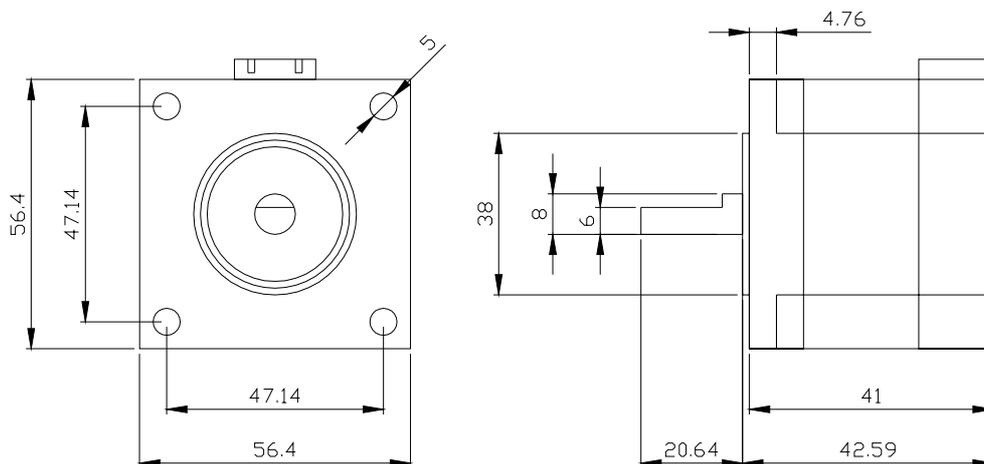


Figure 4-2

### 4.4.2 Twin pot

The Twin pot is a double potentiometer in the same frame. The two potentiometers inside must have complementary action (i.e. one wiper grows up from zero to Vcc meanwhile the second wiper reduces from Vcc to zero - see Figure 4-3 below).

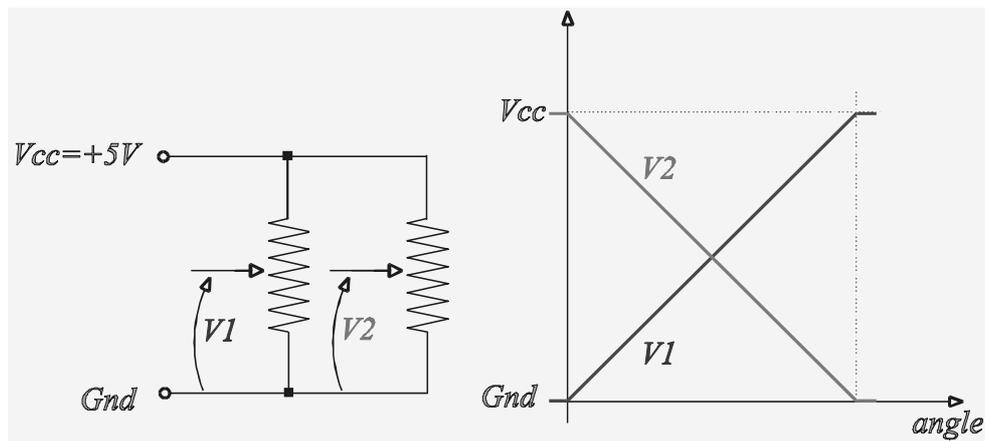


Figure 4-3

The following part numbers resulted suited to work with eps-ac0:

- 1) CONTELEC twin hall sensors 170° Type code VERT-X 2841 417 225.
- 2) BOURNS twin potentiometers 180° Type Code 6657S-466-502.
- 3) MCB twin potentiometers 85° Type Code PMR 410 or PMR426.

The CONTELEC is without brushes but drains a high level of current (about 15 mA). The MCB has the advantage of a spring in the shaft. This spring neutralizes the dead zone in the tiller side getting a strongly accurate straight-ahead matching; unfortunately MCB has a limited angle (85°).

Obviously, the above information states only these parts are suited for the eps-ac0; no reliability evaluation is given here.

Other sources are possible on request, but must be tested for approval.

## 4.5 Feedback sensors

Feedback sensors are mandatory to close the loop in manual mode if a twin pot is mounted on the steering wheel.

Feedback sensors are strongly suggested (to improve safety) in manual mode if a stepper motor is mounted on the steering wheel (open loop).

Eps-ac0 may handle two different configurations for the feedback sensors:

- 1) Incremental encoder in the motor shaft together with a feedback potentiometer on the steered wheel.
- 2) Incremental encoder in the motor shaft together with one (or two) toggle switch(es) in the straight ahead (and 90 degrees) position of the steered wheel.

On request, in the closed loop application only, eps-ac0 may work also with two encoders in the motor shaft together with a straight ahead toggle switch.

### 4.5.1 Encoder in the motor shaft and a Feedback Potentiometer

One possible arrangement for the feedback sensor consists of (see Figure 4-4):

- 1) Feedback encoder in the motor shaft.
- 2) Feedback potentiometer on shaft of the steering motor gear box.

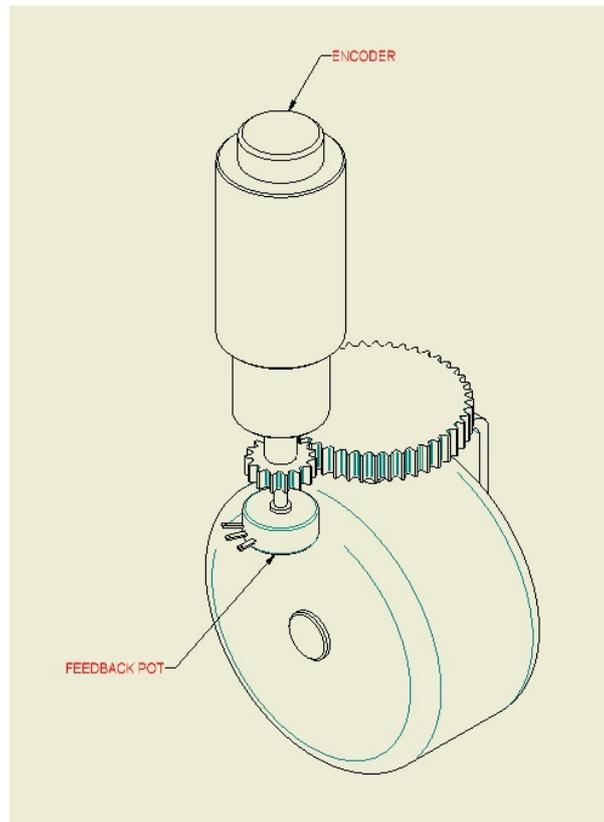


Figure 4-4

#### 4.5.1.1 Feedback potentiometer

The feedback potentiometer is used for both, encoder initialisation and redundancy on the steered wheel angle measurement. Normally the feedback potentiometer is multiturn (5 or 10 turns) 5K hybrid technology mounted on the output shaft of the steering gearbox (see Figure 4-4).

## 4.5.2 Encoder in the motor shaft and one (two) toggle switch(es)

It consists of (see Figure 4-5):

- 1) Straight ahead toggle switch on the input CNA#3 and GND.
- 2) 90 degrees toggle switch on the input CNA#2 and GND.
- 3) Feedback encoder on the steering motor shaft.

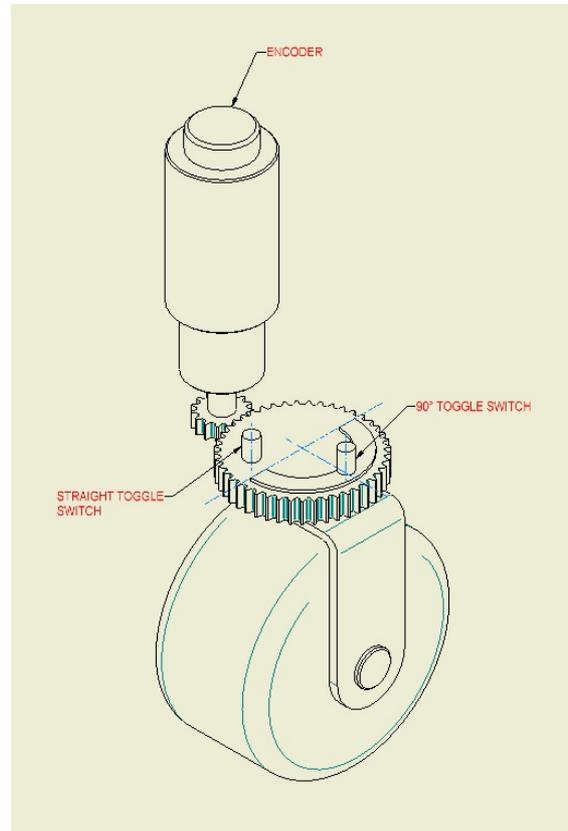


Figure 4-5

### 4.5.2.1 Straight ahead toggle switch

The straight ahead toggle switch must be of NPN type (i.e. it must connect a minus battery to CNA#3).

A possible arrangement for the straight-ahead switch (proximity switch) is shown in Figure 4-6 below. The proximity switch is connected to the truck frame; the Iron plate rotates together with the steered wheel.

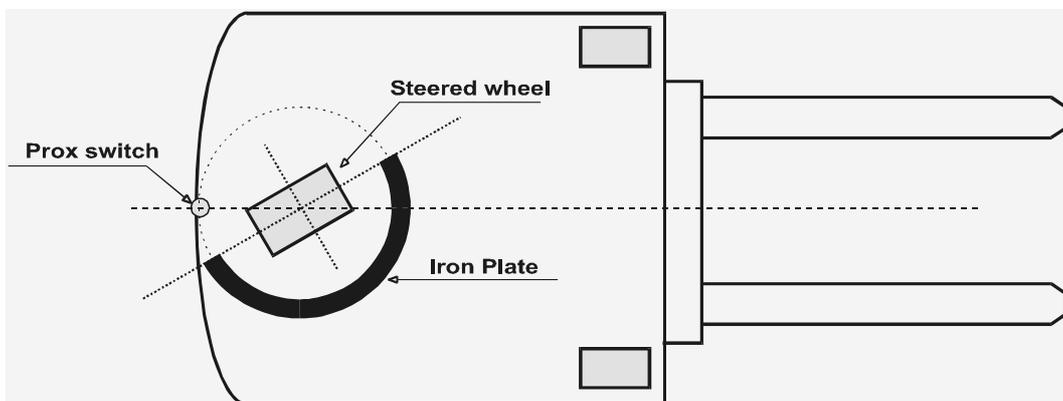


Figure 4-6

It is handled this way:

- 1) At key-on, the eps-ac0 turns the steering motor moving in either CW or CCW side, according to whether the output level from the straight ahead switch is high or low (in the above sketch a proximity sensor is used as a straight ahead switch).
- 2) When the falling edge on the prox switch is detected, the encoder counting is initialized to 0 and the steered wheel is centered.
- 3) Then the encoder counting is continuously updated to measure the steered wheel angle.

At key on, the Iron plate (with the shape shown in Figure 4-6), provides the correct direction in which the eps-ac0 must turn the steering motor in order the falling edge on the proximity switch is detected.

An option POT UP SW1 EDGE (see 12.4.1.12) determines the direction where the steered wheel rotates to seek the straight ahead switch (i.e. it specifies if the steered wheel at the initial alignment is oriented with the iron plate in its right or left side). Together with the straight-ahead switch, a second toggle switch could be adopted to detect when the steered wheel is in the 90 degrees limiting position. This second toggle switch must be connected to CNA#2 and GND (minus battery).

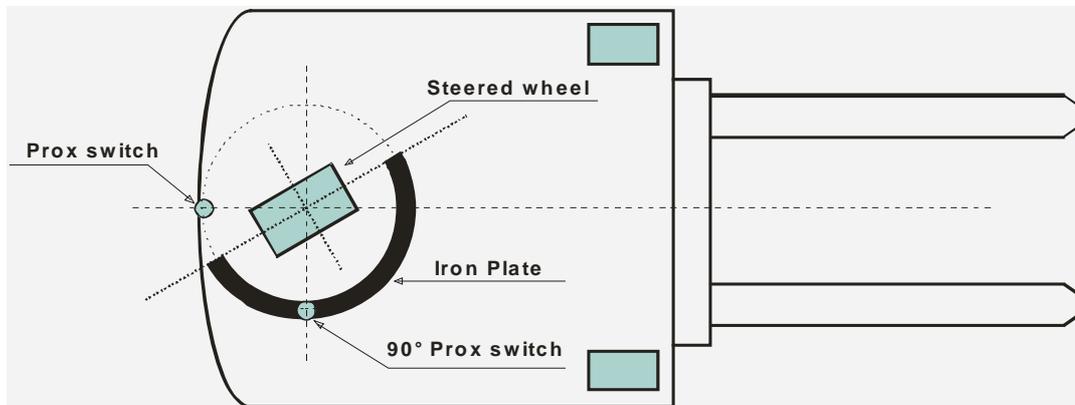


Figure 4-7

### 4.5.3 Feedback Encoder

One big advantage of our eps-ac0 controller is that it can work with a cost-effective very low-resolution encoder. Our competitors normally need a sensor bearing with 32 or higher pulses/rev; our eps-ac0 works also with a cheap encoder having 4 pulses/rev. That is more than enough for the angle measurement: in fact, with a total reduction of 1:200 and a 4 pulses/revs resolution, we have 1600 events (encoder transitions) within 180° of the steered angle. So the angle measurement is determined with quanta of  $180/1600=0.112$  degrees. This is possible because our patent system does not use the encoder for the AC motor control; it works completely sensorless.

Following this statement, we have developed, together with a Zapi's partner AC-motor-brand, a 4 pulses/rev discrete encoder. It is an external device (not integrated in the ball bearing) mounted in the backside of the motor (see Figure 4.8 below showing a 300 W AC Motor by "Best Motor" brand). The advantages of this solution are both, money saving and effective time saving in case of encoder replacement.



Figure 4-8



*Note: On request, it is possible to use the encoder for the motor control. In this case, the SW must know the encoder resolution together with the poles-pair number. The encoder resolution and the motor poles pair (the controller can handle), will be specified in the headline of the handset showing something like:*

*EPSAC0S2A ZP0.70*

*That means:*

*EPSAC0=Eps-ac0 steering controller*

*S= Stepper motor  
2= poles pair number  
A= 32 pulses/rev encoder*

*ZP= SW release type Zapi  
0.70= SW release number 0.70*

*The command configuration is specified through the first letter after EPSAC0 in the following list:*

*S= Stepper Motor  
P= Twin Pot  
C= via CAN Bus Position  
D= via CAN Bus Speed*

*The encoder resolution is given by the last letter before of the SW release in the following list:*

Q= 4 pulses/rev  
S= 6 pulses/rev  
W= 16 pulses/rev  
A= 32 pulses/rev  
K= 48 pulses/rev  
B= 64 pulses/rev

*The letters to specify the poles pair number and the Encoder resolution are present only if the SW includes the function for controlling the motor with the encoder.*

---

## 5 AUTC MODE

Eps-ac0 may perform an automatic centering operation (AUTC).

AUTC means the steered wheel shall be aligned straight-ahead following a centering request. The centering request can be provided via CAN Bus. As alternative, it is possible to use wired requests. For example:

- 1) in a configuration with feedback pot and feedback encoder, it is possible to use inputs CNA#3 and CNA#2 for the centering request (redundancy is recommended).
- 2) in a configuration with toggle switches and feedback encoder, when input CNA#1 is not used, it is possible to use inputs CNB#6 and CNA#1 for the centering request (redundancy is recommended).

In case of AUTC a customized software must be developed.

# 6 CONNECTING DIAGRAMS

Below we have a collection of suggested connecting diagrams. They correspond to the main configurations. On request it is possible to choose also customized proposals or wiring modifications.

## 6.1 Power Connecting Diagram

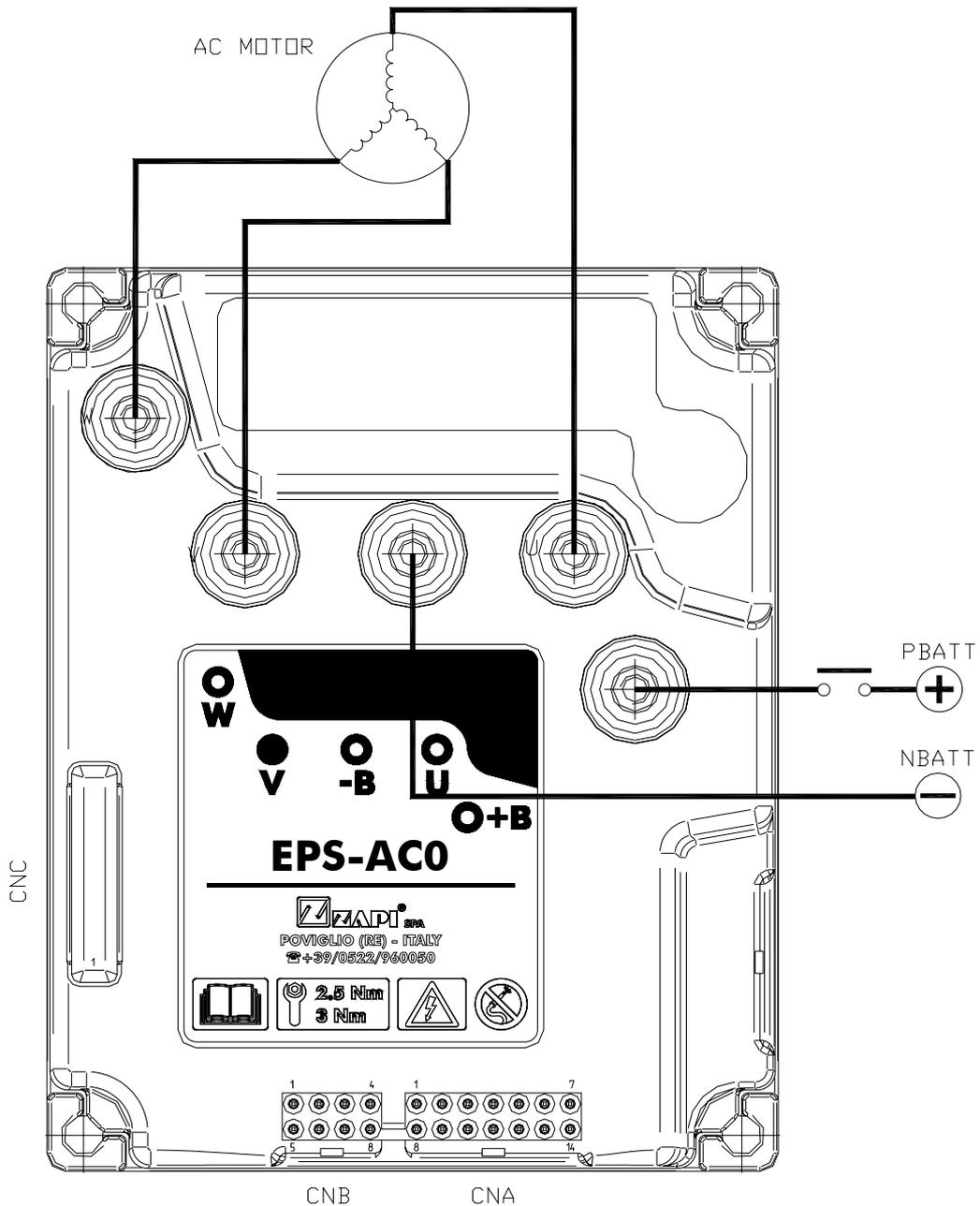


Figure 6-1

## 6.2 EPS-AC0 Stepper Motor diagram

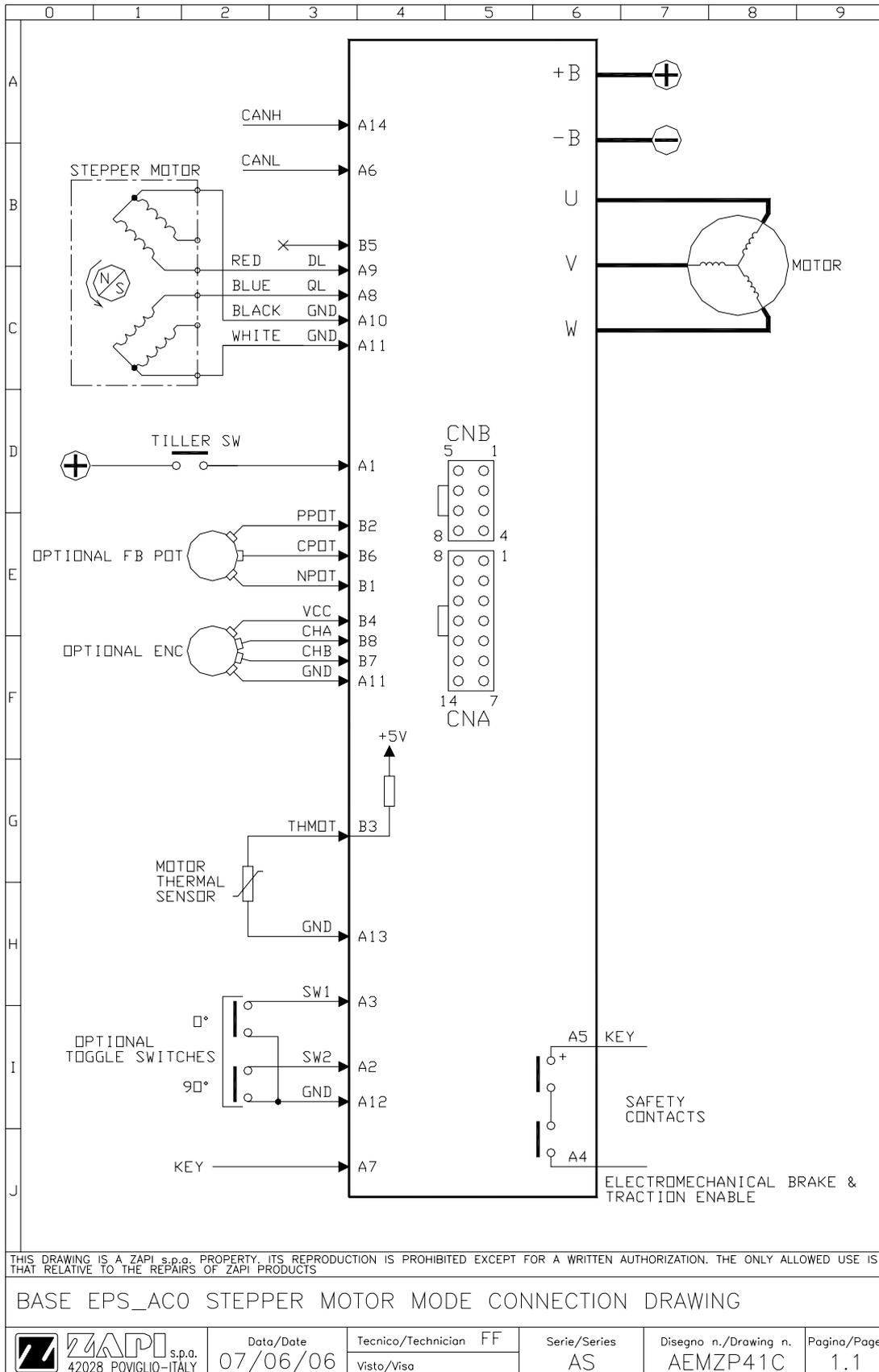


Figure 6-2

## 6.3 EPS-AC0 Twin pot diagram

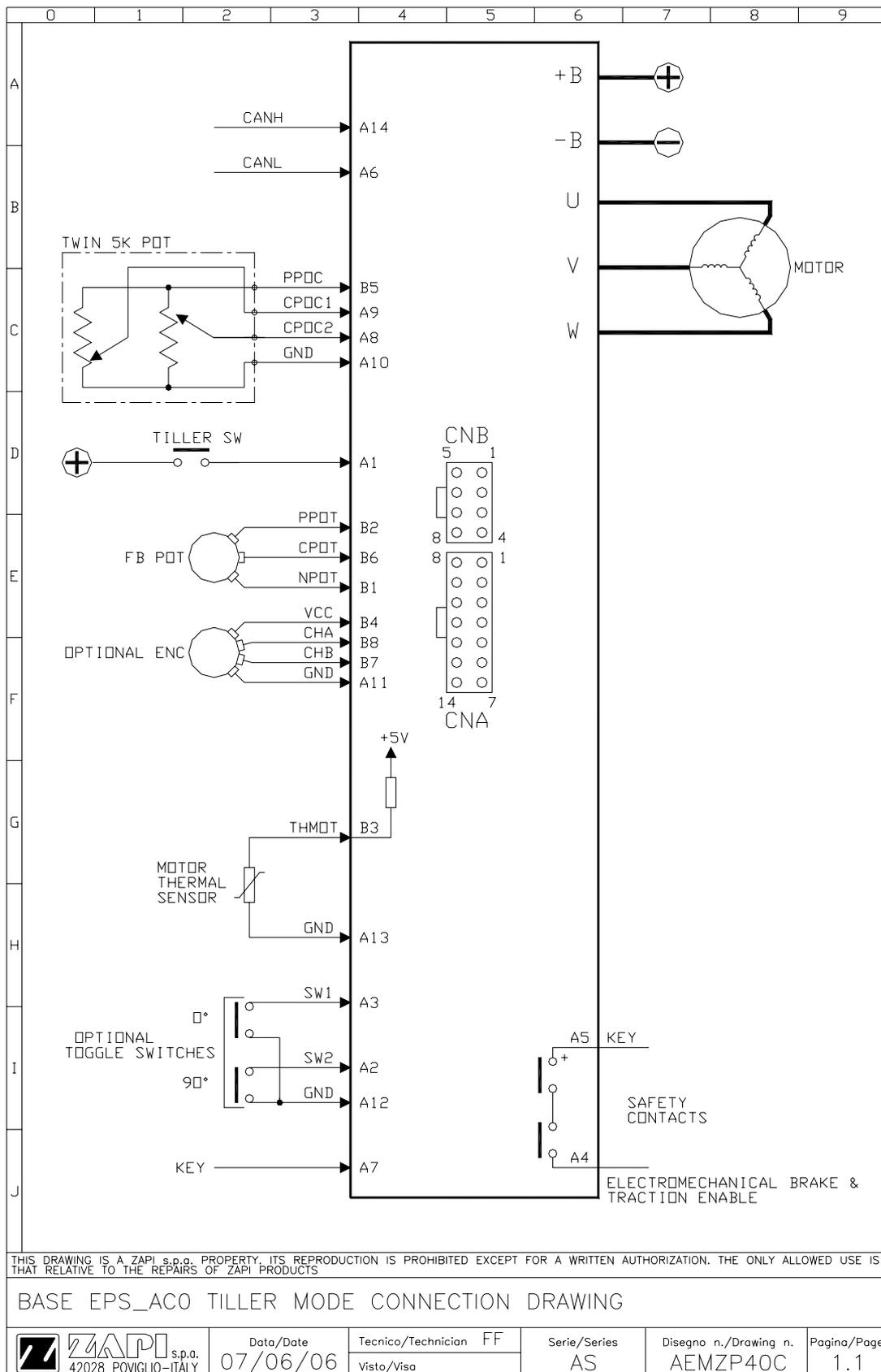


Figure 6-3

# 7 CONNECTIONS: SUGGESTIONS AND CAUTIONS

Read the following suggestions to get a correct connection of the steering equipment.

---

## 7.1 Stepper Motor connections

The stepper motor has 4 connections: two are the stepper motor channels (CNA#9 and CNA#8) and two are the common (negative) references (CNA#10 and CNA#11). In the past we had 6 wires connected between stepper motor and eps-ac. We consider this 4-wire connection fulfils the norm because it is still possible to detect all of the single stepper motor electrical fault.



*Note: The stepper motor should be connected with two distinct common (negative) references (CNA#10 and CNA#11). We advice against using just one common wire. That is because it takes long delay to detect when a single common wire is broken.*

---

---

## 7.2 Twin pot connections

The twin pot is connected, in alternative to the stepper motor, between CNB#5 (PPOC: 5 V positive supply), CNA#10 (negative supply), CNA#9 (CPOC1: 1<sup>st</sup> wiper), CNA#8 (CPOC2: 2<sup>nd</sup> wiper). CNB#5 is connected to a 5 Vdc supply source through a 22 ohms resistance. Take care the supply current of the Twin pot stays lower than 5 mA.

---

## 7.3 Encoder connections

The encoder may be supplied either with 5 Vdc or 13 Vdc (factory set jumper J8) on CNB#4 (default set is 5 Vdc on CNB#4). A 10 ohms resistance is connected between the internal supply source and the pin CNB#4. The encoder outputs may be either open collector NPN type or Push-Pull type.

---

## 7.4 Feedback pot connections

When a feedback pot is adopted it will be connected between CNB#2 (PPOT: positive supply), CNB#1 (NPOT: negative supply), CNB#6 (CPOT: wiper). Pay attention, inside the eps-ac0, a 470 ohms resistance is connected between PPOT and 5 V supply and also between NPOT and the minus battery. That is done

in order it will be possible to detect if a feedback pot connection breaks (see Figure 7-1 below): when  $V_{out}$  overtakes 4.7 V or is lower than 0.3 V an alarm occurs.

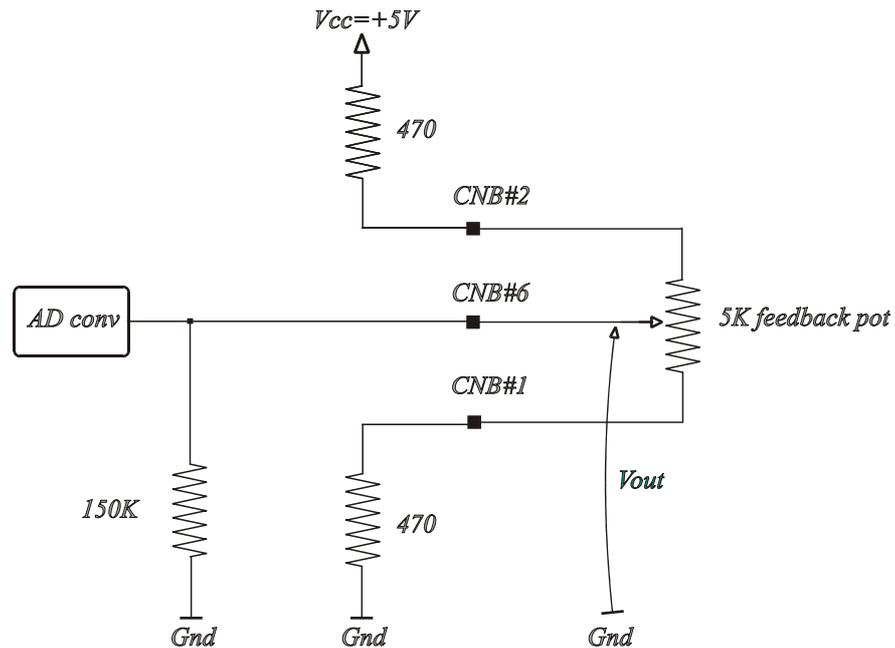


Figure 7-1

## 7.5 Digital Inputs connections

There are three digital inputs available.

Two of them must be GND connected to work properly. Their function primarily is:

CNA#3: Input for the straight-ahead toggle switch

CNA#2: Input for a 90° toggle switch

When the application adopts the feedback pot instead of the straight-ahead toggle switch, CNA#3 and CNA#2 have the function to limit the maximum steered angle in CW and CCW side (in alternative, it is possible to use them as centering request).

CNA#3 and CNA#2 are detected low if they are lower than 1.3 V.

CNA#3 and CNA#2 are detected high if they are higher than 6.6 V or open.

Besides there is a third digital input (CNA#1). Default choice wants CNA#1 connected to a plus battery (default choice) to work properly.

CNA#1 is detected low if it is open or lower than 5.17 V.

CNA#1 is detected high if it is higher than 11 V.

By changing jumper J12 it is possible to reverse CNA#1 logic. Then CNA#1 must be connected to a minus battery to work properly.

CNA#1 is detected low if it is lower than 1.3 V.

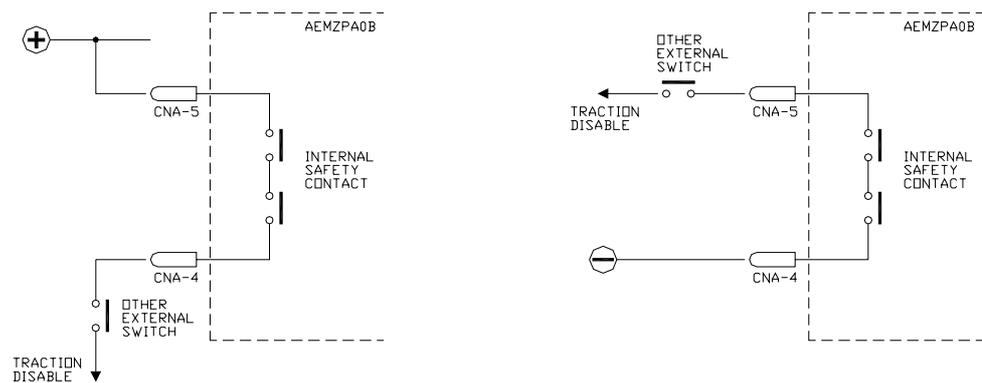
CNA#1 is detected high if it is open or higher than 3.3 V.

## 7.6 Safety contacts

The Eps-ac0 provides an internal safety contact accessible through connector pins CNA#5 and CNA#4. It should be used to stop the traction and to enable an electromechanical brake when a steering alarm occurs. This safety contact is closed when the key switch is turned on. The contact opens where there is a steering alarm. This safety contact is floating, that means it's possible to connect it either to the plus battery or to the minus battery. **Ensure that the pin #5 is connected to an equal or higher voltage than pin #4.** For safety two cascaded switches are internally connected between CNA#5 and CNA#4. The Main microprocessor manages the first contact; the Supervisor microprocessor manages the second contact.



**Note:** If the safety switch is connected in series with external switches (dead-man switch, tiller switch or similar) it's recommended that the steering safety switch should be directly connected to the supply source (plus battery or minus battery) with no interposed switches (it should be the first the chain: see Figure below).



## 7.7 Motor thermal sensor connections

Eps-ac0 handles a motor thermal sensor: it should be KTY184-130 type. Through this sensor, the eps-ac0 measures the motor temperature: when DIAG MOTOR TEMP is set ON, and the motor temperature overtakes 150 degrees, an alarm occurs. Input CNB#3 is configured with a aboard 1K Pull-up resistor suited to receive the analog thermal sensor between this input and a negative (CNA#13).

# 8 INSTALLATION: SUGGESTIONS AND CAUTIONS

Read and respect the following suggestions to avoid problem during installation and in the definitive releasing.

---

## 8.1 Thermal consideration

- 1) The heat generated by the power block must be dissipated. For this to be possible the compartment must be ventilated and the heat sink materials ample.
- 2) Normally eps-ac0 does not ask for a forced ventilation: if the cooling is poor, a possible solution could be to redirect a part of the forced air flow of the traction controller toward the eps-ac0.
- 3) Abnormal ambient air temperatures should be considered. In situations where either ventilation is poor, or heat exchange is difficult, forced air ventilation should be used.
- 4) The thermal energy dissipated by the power block module varies and is dependent on the current drawn and the duty cycle.

### 8.1.1 Controller with Base Plate

Installs the controller with the base-plate on a flat metallic surface that is clean and unpainted; suggested characteristics are: planarity 0.05 mm and roughness 1.6  $\mu\text{m}$ . Apply a light layer of thermo-conductive grease between the two surfaces to permit better heat dissipation.

### 8.1.2 Controller with finned Heatsink

Sometimes the base plate installation cannot be adopted. Due to positioning problems or to a low thickness truck frame, it is necessary to adopt a finned dissipation combined with one or more fans.

- 1) The air flux should hit the fins directly, to maximize the cooling effect.
- 2) In addition to fans, also air-ducting systems can be used to maintain low the temperature of the controller.
- 3) It is necessary to ensure that cold air is taken from outside the controller compartment and hot air is easily pushed away from the controller compartment.
- 4) It is mandatory to avoid that the cooling air is re-circulated inside the controller compartment.

---

## 8.2 General suggestion

For a proper installation take care of the following recommendations:



***Never connect SCR low frequency chopper with AC Motor Inverter because the Rail capacitors alter the SCR choppers' work. If it is necessary to use two or more control units (e.g. traction + lift. + steering controller), they must belong to the ZAPIMOS family.***



***Do not connect the inverter to a battery with a nominal value different from the value indicated on the controller plate. If the battery value is greater, the MOS may fail; if it is lower, the control unit does not "power up".***



***During battery charge, disconnect the controller from the battery.***



***Supply the controller only with battery for traction; do not use a power supply.***



***When the inverter is installed, simulate a steering alarm and verify that both traction and electromechanical brake shall be de-energized in a very short time.***



***After the battery is disconnected, the Rail capacitor remains charged for some minutes; if you need to work on the inverter, discharge them using a  $10 \Omega \div 100 \Omega$  resistance connected from the +Batt to the -Batt terminals in the controller side.***



***Take care all the inductive devices in the truck (horn, solenoid valves, coils, contactors) have a proper transient suppression device.***

---

## 8.3 Connection cables

- 1) For the auxiliary circuits, use cables at least 0.5 mm<sup>2</sup> section.
- 2) For power connections to the motor and to the battery, use cables having section of 4-6 mm<sup>2</sup> (as a minimum).
- 3) The power cables length must be as short as possible to minimize power losses.

- 4) For the optimum inverter performance, the cables to the battery should be run side by side and be as short as possible.
- 5) They must be tightened on controller power posts with a Torque of 2.5-3 Nm.

---

## 8.4 Fuses

- 1) Use a 6.3-10 A fuse for protection of the auxiliary circuits.
- 2) Use a 32 A fuse for protection of the power stage.

---

## 8.5 Contactors

According to EN1175 5.9.6, a contactor to cut the line to the eps-ac0 is not strictly required. In fact in an AC system, the steer is automatically de-energized when a power failure occurs. In a DC system with permanent magnet motor instead, a short circuit in a power device, gets the steering motor rotates at maximum speed (and so it is necessary to cut off the line from the controller).



***A power contactor is still useful to remove the battery from controller when a power failure occurs. This is useful in order to limit the time in which a damaged controller remains battery connected. When a power contactor is used, the contactor coil shall be connected to a power supply through the eps-ac0 safety contact.***

---

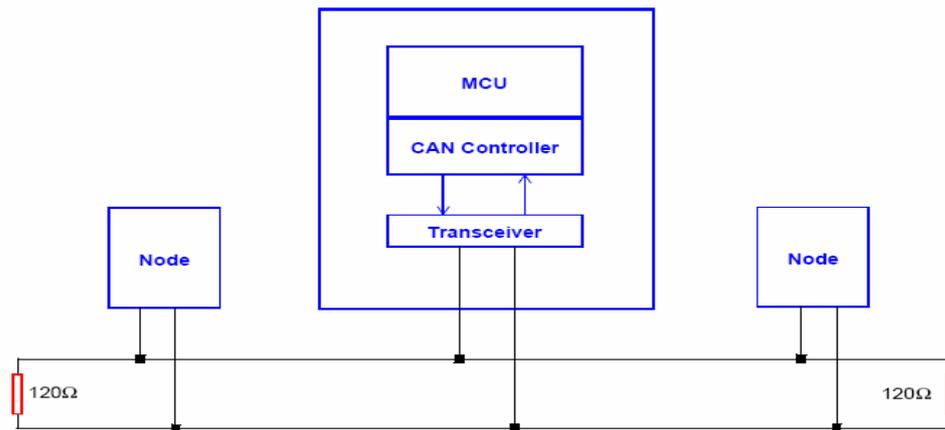
---

## 8.6 Installation of a CAN Communication System

---



*CAN stands for Controller Area Network. It is a communication protocol for real time control application. CAN operates at data rate of up to 1 Megabits per second. It was invented by the German company Bosch to be used in the car industry to permit communication among the various electronic modules of a vehicle, connected as illustrated in the figure below:*



---

The best cable for can 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 a cable with a shield connected to the frame of the truck. Sometimes it is sufficient a simple double wire cable or a duplex cable not shielded.

In a system like an industrial truck, where power cables carry hundreds of Ampere, there are voltage drops due to the impedance of the cables, and that could cause errors on the data transmitted through the can wires.



***The eps-ac0 drains low level of current and so low section cables (4 mm<sup>2</sup>) are adopted for the power connections. This could be a drawback: in fact, a low section cable has higher reactance (impedance) than a wide section cable. As a consequence the noise generated on the minus battery cable, by the CAN lines switching, will be a wide amplitude spike. So, when it is possible, we suggest to use a (as short as possible) cable of a wide section for the minus battery connection, even for the eps-ac0 and the other low current units in the system.***



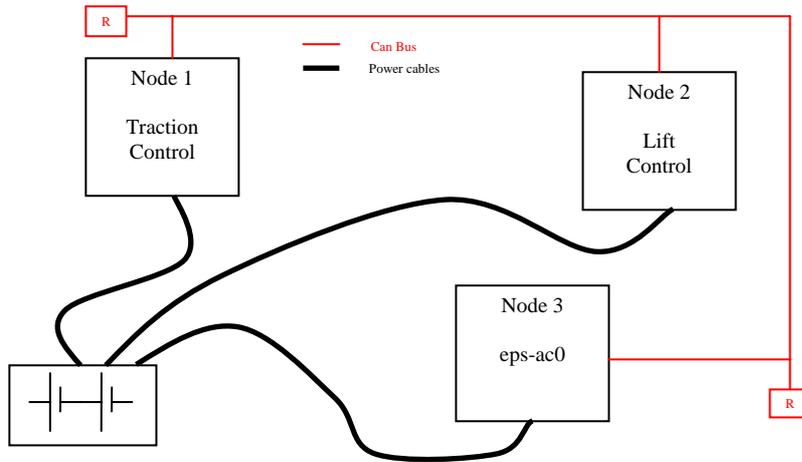
***VERY IMPORTANT: The eps-ac0 has the 120 ohms termination resistance aboard.***

---

In the following figures there is an overview of wrong and right layouts of the cables routing.



**Wrong Layout:**



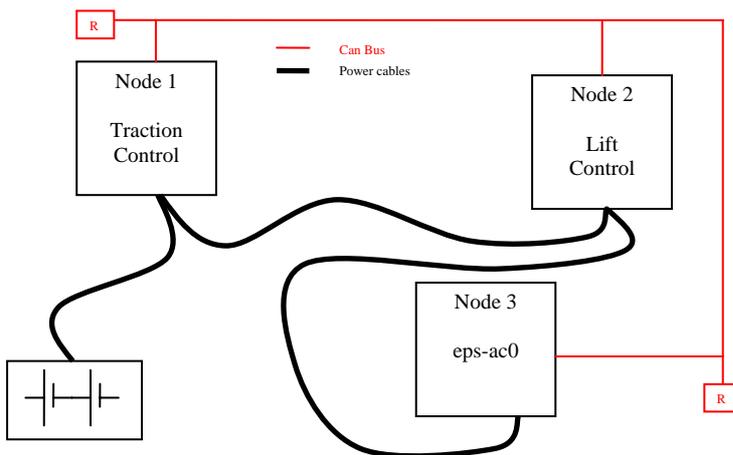
The red lines are can wires.  
The black boxes are different modules, for example traction controller, pump controller and eps-ac0 connected by can bus.  
The black lines are the power cables.

This is apparently a good layout, but can bring to errors in 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:**

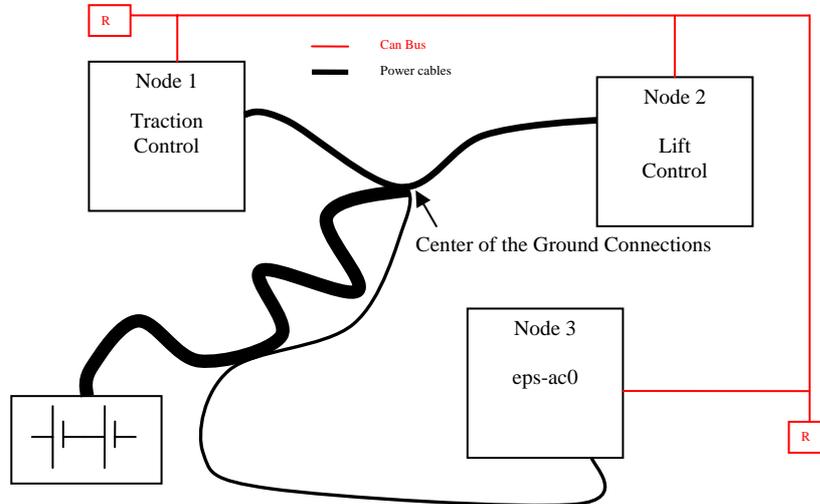


The chain starts from the –BATT post of the controller that works with the highest current, and the others are connected in a decreasing order of power.

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, the best way to deal this configuration is to create a common ground point (star configuration)



### Correct Layout:



In this case the power cables starting from the two similar controllers must be as short as possible. Of course also the diameter of the cable concurs in the voltage drops described before (higher diameter means lower impedance). So, in this last example, the cable between the minus of the Battery and the common ground point (pointed by the arrow in the image) must be dimensioned taking into account thermal and voltage drop problems.



### Can advantages

*The complexity of today systems needs more and more data, signal and information must flow from a node to another. CAN is the solution to different problems that arise from this complexity*

- *simplified design (readily available, multi sourced components and tools)*
- *lower costs (less and smaller cables )*
- *improved reliability (fewer connections)*
- *analysis of problems improved (easy connection with a pc to read the data flowing through the cable).*

## 8.7 Wiring: I/O connections

After crimping the cable, verify that all strands are entrapped in the wire barrel. Verify that all the crimped contacts are completely inserted on the connector cavities. For information about the mating connector pin assignment see the description of the connectors in topic 9.



***A cable connected to the wrong pin can lead to short circuits and failure; so, before turning on the truck for the first time, verify with a multimeter the continuity between the starting point and the end of a signal wire.***

---

## 8.8 Safety features



***ZAPI controllers are designed according to the prEN954-1 specifications for safety related parts of control system and to UNI EN1175-1 norm. The safety of the machine is strongly related to installation; length, layout and screening of electrical connections have to be carefully designed.***

***ZAPI is always available to cooperate with the customer in order to evaluate installation and connection solutions. Furthermore, ZAPI is available to develop new SW or HW solutions to improve the safety of the machine, according to customer requirements.***

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

---

Eps-ac0 implements a double  $\mu$ C structure to comply with the Category#3 specification. The second  $\mu$ C main task is to check correct functionality of the first  $\mu$ C, whose main task is to control the steering motor. Basically, the two microcontrollers implement a double check control of the main functions. The two  $\mu$ Cs are both CAN Bus connected. This characteristic makes possible the eps-ac0 receives the steering command (wished steered wheel position) via CAN Bus fulfilling the norm.

## 8.9 EMC



***EMC and ESD performances of an electronic system are strongly influenced by the installation. Special attention must be given to the lengths and the paths of the electric connections and the shields. This situation is beyond ZAPI's control. Zapi can offer assistance and suggestions, based on its years experience, on EMC related items. However, 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).***

---

EMC stands for Electromagnetic Compatibility, and it represents the studies and the tests on the electromagnetic energy generated or received by an electrical device.

**Emission** refers to the energy radiated from the controller and the harness.

**Immunity** can be divided in two main branches: rejection from external electromagnetic fields and from electrostatic discharges (ESD).

So the analysis works in three directions:

- 1) Emission
- 2) Electromagnetic Immunity
- 3) ESD rejection.



***When possible it is strongly recommended preventing Emission and Immunity problems by locating the controllers inside a metallic enclosure. In most cases, a truck with a metallic enclosure will avoid EMC problem.***

---

### 8.9.1 Emission

**Emission** refers to the electromagnetic disturbances that the device generates in the surrounding space. Countermeasure should be adopted to prevent the propagation of those disturbances. We talk about “conduction” issues when guiding structures such 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 which are working at high frequency and generate RF energy. **Wires and cables are responsible for the spreading of this RF disturbance because they works as antennas**, so a good layout of the cables and their shielding can solve the majority of the emission problems.

Three ways can be followed to reduce the emissions:

- 1) **SOURCE OF EMISSIONS:** finding the main source of disturbs and works on it.
- 2) **SHIELDING:** enclosing contactor and controller in a shielded box; using shielded cables.
- 3) **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 frame is generally a suggested not expensive solution to reduce the emission level.

### 8.9.2 Electromagnetic Immunity

The **electromagnetic immunity** concerns the susceptibility of the controller to external electromagnetic fields and their influence on its correct work made. These tests are carried out at determined levels of electromagnetic fields, to simulate external undesired disturbances and verify the electronic device response. Here are some suggestions to improve the electromagnetic immunity:

- 1) **SHIELDING:** enclosing controller and wiring when possible on a shielded box; using shielded cables.
- 2) **LAYOUT:** hide the exposed wires, which are connected to the controller, behind metallic part working like natural barriers.
- 3) **FERRITES:** embrace the exposed wires, connected to the controller, with a split or solid ferrite.
- 4) **BY-PASS CAPACITOR:** connect an interference suppression capacitor (Y type) between the minus battery and the truck frame, as close as possible to the controller.

### 8.9.3 ESD

When an accumulation of charge occurs in a part insulated from the ground, it may discharging in a shot when turning in contact with a part having different potential. This phenomenon is called Electrostatic Discharge (ESD).

In forklift trucks applications, special attention should be adopted for avoiding ESD. **The main rule is that it is always much easier and cheaper to avoid ESD from being generated, than to increase the level of immunity of the electronic devices.**

ESD happens when there is a rapid transfer from a charged part to another. This rapid transfer has, in turn, two important effects:

- 1) It can determine, by induction, disturbs on the signal wiring and thus create malfunctions. This effect is particularly critical in modern machines, with CAN Bus communications, which are spread everywhere on the truck and which carry critical information.
- 2) 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 an intermittently malfunction to a completely failure of the electronic device.

Three ways can be followed to prevent damages from ESD:

- 1) **INSULATION:** To prevent the controller from ESD, it is necessary to consider that the operator is most of the time the source of ESD. When it gets in touch with a device on the dashboard having metallic head terminal, the accumulated charge will be directed from the head terminal to the wires of the device towards the other units in the truck (e.g. the CAN Bus wires or the wires of the stepper motor on the dashboard could be the transmission mean). As consequence a huge inrush current will be generated getting the controller cut off or damaged.



***To prevent ESD risk it is necessary to avoid that the devices connected to the CAN communication system have exposed metallic head terminals. The operator shall not get in touch with any metallic part of the devices CAN Bus connected.***

---

- 2) **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 work like a “local earth ground”, absorbing excess charge.



***It is strongly suggested to connect to the truck frame all the parts of the truck that can get in touch with the operator (who is most of the time the source of ESD). For example, we strongly suggest to connect the stepper motor frame to the truck frame.***

---

- 3) **PREVENTION:** Another important issue is the storing and handling of ESD-sensitive electronic parts. Then, 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. Use anti-static containers when transferring ESD-sensitive material.

---

## 8.10 Fighting the dither

In Closed Loop application with potentiometers, the quantum nature of the Analog to Digital conversion, generates dither on the steered wheel. This is a continuous rolling of the steered wheel from a little bit right to a little bit left around the commanded position. Obviously, both the potentiometers (SP POT and FB POT) have noise and contribute to the problem.

There are some countermeasures to reduce or neutralize the dither.

- 1) Use shielded cable for the connections of the potentiometers (especially for the SP POT). The shielded cable reduces the noise in the wiper voltage. Connect the shield to a GND pin of the eps-ac0 connectors.
- 2) Use the FB ENC instead of the FB POT as feedback sensor. The Encoder has not noise. When the Encoder is stopped in a position, the Encoder counting is absolutely constant.
- 3) Reduce the gain of the Closed Loop. It means KP and POS. ACCURACY parameters must be decreased. When the gain reduces, the modification of the position error due to noise, are less amplified giving less dither; but less accuracy is got in the final pursuing at the wished position.

# 9 DESCRIPTION OF THE CONNECTORS

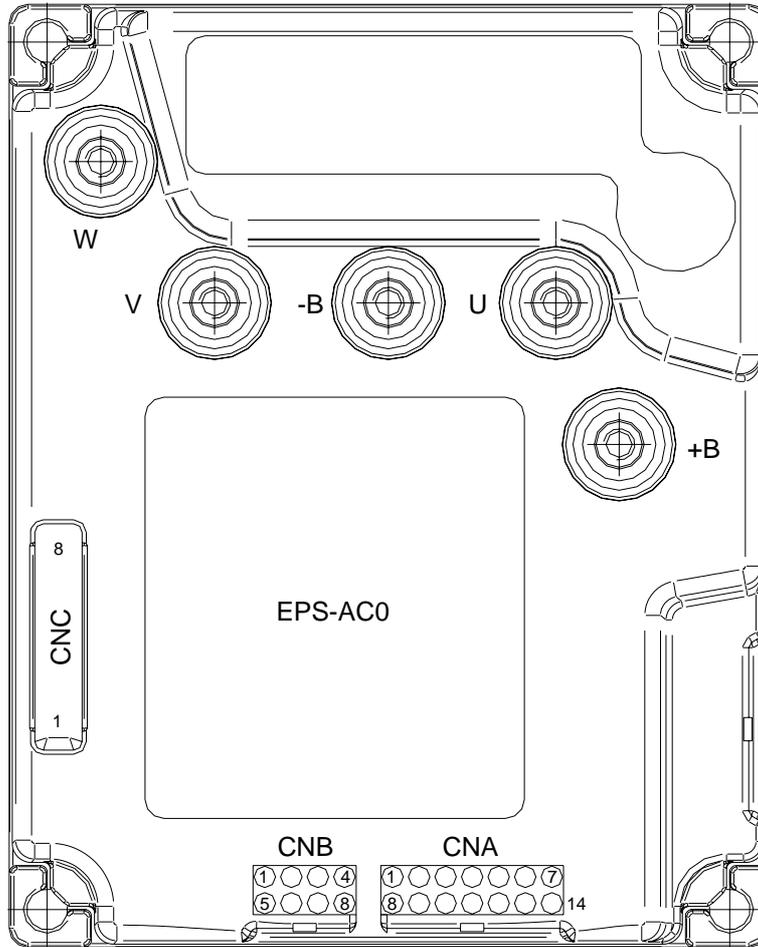


Figure 9-1

## 9.1 Connectors of the logic

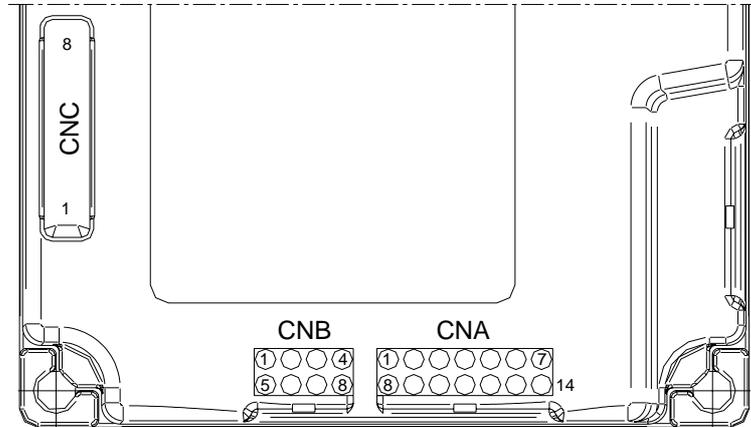


Figure 9–2

### 9.1.1 CNA connector

A1	DRIVE SWITCH	Traction Travel Demand Input.
A2	SW2	2 <sup>nd</sup> Toggle Switch or Left Limit Switch (LLS).
A3	SW1	1 <sup>st</sup> Toggle Switch or Right Limit Switch (RLS).
A4	NK1	Safety Switch Lower Voltage Point.
A5	K1	Safety Switch Higher Voltage Point.
A6	CANL	Can Bus Low.
A7	KEY	Key in (24-36 V <sub>batt</sub> ).
A8	CPOC2 / QL	2 <sup>nd</sup> SP POT Wiper or Stepper Motor Q line.
A9	CPOC1 / DL	1 <sup>st</sup> SP POT Wiper or Stepper Motor D line.
A10	NPOC	Twin SP POT Negative Supply (GND).
A11	GND	GND. Encoder Negative Supply
A12	GND	GND. SW1 & SW2 Negative.
A13	GND	GND. Motor Thermal Sensor Negative.
A14	CANH	Can Bus High.

### 9.1.2 CNB connector

B1	NPOT	FB POT Negative Supply.
B2	PPOT	FB POT Positive Supply.
B3	THMOT	Motor Thermal Sensor (KTY84-130) Input.
B4	+5VDC	Encoder Positive Supply.
B5	PPOC	Twin SP POT Positive Supply (5 Vdc).

B6	CPOT	FB POT Wiper.
B7	CHB	Encoder Channel B.
B8	CHA	Encoder Channel A.

### 9.1.3 CNC connector

C1	PCLRXD	Positive serial reception.
C2	NCLRXD	Negative serial reception.
C3	PCLTXD	Positive serial transmission.
C4	NCLTXD	Negative serial transmission.
C5	GND	Negative console power supply.
C6	+12	Positive console power supply.
C7	FLASH	Must be connected to C8 for the Flash memory programming (if used).
C8	FLASH	Must be connected to C7 for the Flash memory programming (if used).

## 9.2 Description of power connections

View of the power bars:

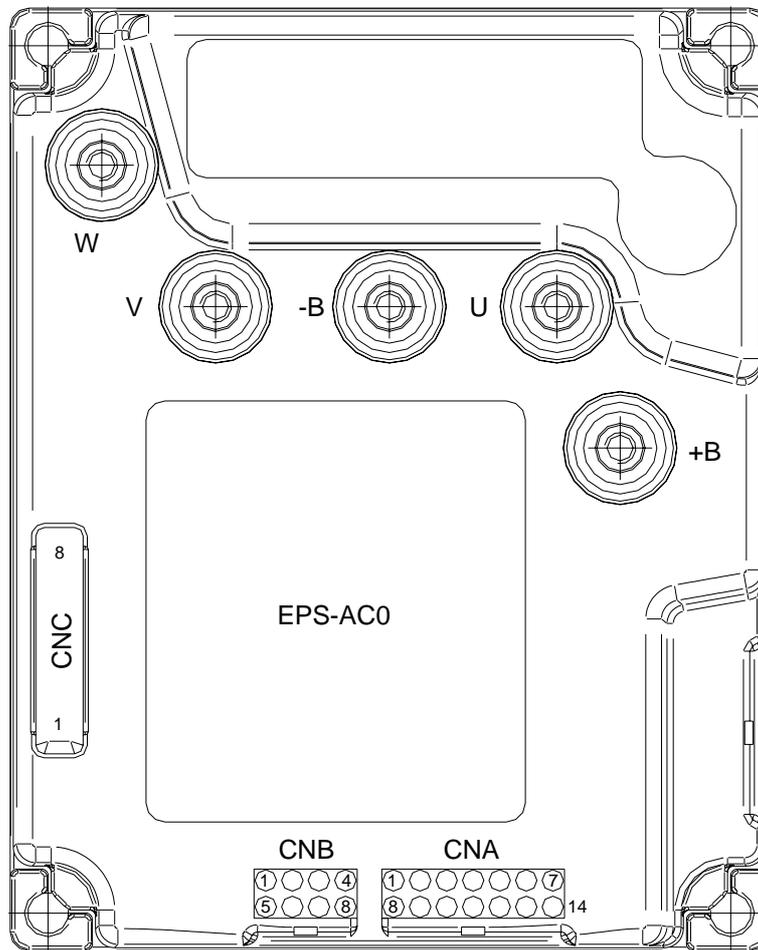


Figure 9-3

- |         |  |
|---------|--|
| -B      | Negative of the battery.   |
| +B      | Positive of the battery.   |
| U; V; W | Connection bars of the three motor phases; follow this sequence and the indication on the motor. |

# 10 INSTALLATION PROCEDURE

As stated in the topic 4.5 there are two equipments that it is possible to adopt for the feedback sensor:

- 1) Encoder and Feedback pot.
- 2) Encoder and toggle switches.

The standard handling in both cases consists in performing an automatic centering at key-on. The automatic centering at key-on is used to initialize the incremental encoder.

When a straight-ahead switch is used to initialize the encoder, the steered wheel rotates automatically until an edge is detected on the straight ahead switch.

When a Feedback pot is used to initialize the encoder, the steered wheel rotates automatically until the potentiometer reaches the straight-ahead position.

On request, it is possible to avoid the automatic centering at key-on. In case of feedback pot, the feedback encoder counting will be initialized at key-on with the angle measured on the feedback pot; in case of the toggle switches, the truck speed will be limited until the driver rotates the steered wheel and an edge on the straight ahead switch is detected.

Several feedback sensors and command sensor combinations are not described below. That is because they are not handled yet.

---

## 10.1 Twin Pot with Encoder and Feedback pot: one shot installation procedure

This procedure is relative to the connecting drawings Figure 6-3. It describes the step by step installation procedure to get the prototype working in manual mode: to raise the AUTC function it is necessary to make the complete set-up procedure (see topic 11).

For every truck released on the field, the default set-up shall reply the prototype settings and so no installation procedure is required except for the acquisition of the limiting position (see the quick set-up 11.2).

Carry out the procedure in the following order.

- Step1** Connect the AC motor phases in such a way the phase references U, V, W on the steering motor correspond to the terminals references (U, V, W) on the eps-ac0.
- Step2** In the SET MODEL menu set the SYSTEM CONFIG setting to LEVEL 1 to steer in closed loop with a twin pot in manual mode (RTC). Turn off and on the key in order the setting is acquired.
- Step3** Set the FEEDBACK DEVICE to OPTION #1 to specify your feedback solution is the sole FEEDBACK POT. Switch off the key after the change. (It is necessary to start with the sole feedback pot to avoid a POSITION ERROR due to the unknown scaling between the encoder counting and the feedback pot value before of an encoder learning operation - Step 9 and 11 below).
- Step4** Set option ENCODER CONTROL to OFF.
- Step5** Connect the feedback pot in such a way the FEEDBACK POT reading in the tester menu assumes higher voltage when the FREQUENCY in the tester menu is positive. When a FB POT LOCKED alarm occurs immediately after switching on the key, it means the motor is turning away from the wished position (i.e. FEEDBACK POT decreases when the FREQUENCY is

positive). Then it is necessary to swap the PPOT with NPOT (CNB#2 with CNB#1).

- Step6** Connect the encoder. The encoder supply is between CNB#4 (5Vdc) and CNA#11 (GND): the two channels are CNB#8 (CHA) and CNB#7 (CHB).
- Step7** Verify the reading ENC SPEED in the tester menu is consistent with the reading FREQUENCY in the tester menu. Consistent means that ENC SPEED and FREQUENCY must have the same sign and a close value. If ENC SPEED has a wrong sign, swap CHA (CNB#8) with CHB (CNB#7). If ENC SPEED is not close to FREQUENCY, the encoder resolution is wrong and a different SW is needed (see 12.4.7.12 and 12.4.7.8).
- Step8** If the motor runs well without glitches, it is possible to stay with ENCODER CONTROL to OFF; otherwise, turn ENCODER CONTROL to ON.
- Step9** Verify the steered wheel rotates in the correct direction according to the hand wheel. If it isn't, swap CPOC1 (CNA#9) with CPOC2 (CNA#8).
- Step10** Set the LIMIT DEVICE option to OFF to avoid the maximum angle limitations.
- Step11** Set NUMBNESS parameters to Level 0.
- Step12** Move the hand wheel until the maximum (plus 90 degrees) steered wheel angle is achieved (Increase 1ST ANGLE COARSE - and FINE - if necessary). This position (plus 90 degrees) corresponds to the maximum value of the FEEDBACK POT reading in the TESTER menu.
- Step13** With the steered wheel in the maximum angle (plus 90 degrees), enter and save the adjustment SET MAX FB POT on the hand set to memorize the steer angle feedback pot voltage for the maximum (plus 90 degrees) limit position. If present, the maximum of the FB ENC is recorded too (although it is not shown in the hand set).
- Step14** Move the steering wheel until the minimum (minus 90 degrees) steered wheel angle is achieved (Increase 2ND ANGLE COARSE - and FINE - if necessary). This position (minus 90 degrees) corresponds to the minimum value of the FEEDBACK POT reading in the TESTER menu.
- Step15** With the steered wheel in the minimum angle (minus 90 degrees), enter and save the adjustment SET MIN FB POT on the hand set to memorize the steer angle feedback pot voltage for the minimum (minus 90 degrees) limit position. If present, the minimum of the FB ENC is recorded too (although it is not shown in the hand set).
- Step16** Set FEEDBACK DEVICE to OPTION#2 (feedback pot plus feedback encoder) and recycle the key to enable the steering by encoder.
- Step17** Carry out the complete set-up procedure (see 11.1).

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## 10.2 Twin Pot with Encoder, Straight Ahead Switch and Feedback pot: one shot installation procedure

This procedure is relative to a feedback sensor arrangement consisting of a straight ahead switch, together with the feedback potentiometer and the encoder. This configuration is not much spread. It is useful to have a redundancy in the initialization of the encoder (without straight ahead switch, the feedback encoder is initialized by using the feedback pot only) and a better precision in the straight ahead matching (the feedback pot mounting normally has a dead zone). It describes the step by step installation procedure to get the prototype working in manual mode: to raise the AUTC function it is necessary to make the complete set-up procedure (see topic 11).

For every truck released on the field, the default set-up shall reply the prototype settings and so no installation procedure is required except for the acquisition of the limiting position (see the quick set-up 11.2).

Carry out the procedure in the following order.

- Step1** Connect the AC motor phases in such a way the phase references U, V, W on the steering motor correspond to the terminals references (U, V, W) on the eps-ac0.
- Step2** In the SET MODEL menu set the SYSTEM CONFIG setting to LEVEL 1 to steer in closed loop with a twin pot in manual mode (RTC). Turn off and on the key in order the setting is acquired.
- Step3** Set the FEEDBACK DEVICE to OPTION #1 to specify your feedback solution is the sole FEEDBACK POT. Switch off the key after the change. (It is necessary to start with the sole feedback pot to avoid a POSITION ERROR due to the unknown scaling between the encoder counting and the feedback pot value before of an encoder learning operation - Step 13 and 15 below).
- Step4** Set option ENCODER CONTROL to OFF.
- Step5** Connect the feedback pot in such a way the FEEDBACK POT reading in the tester menu assumes higher voltage when the FREQUENCY in the tester menu is positive. When a FB POT LOCKED alarm occurs immediately after switching on the key, it means the motor is turning away from the wished position (i.e. FEEDBACK POT decreases when the FREQUENCY is positive). Then it is necessary to swap the PPOT with NPOT (CNB#2 with CNB#1).
- Step6** Connect the encoder. The encoder supply is between CNB#4 (5 Vdc) and CNA#11 (GND): the two channels are CNB#8 (CHA) and CNB#7 (CHB).
- Step7** Verify the reading ENC SPEED in the tester menu is consistent with the reading FREQUENCY in the tester menu. Consistent means that ENC SPEED and FREQUENCY must have the same sign and a close value. If ENC SPEED has a wrong sign, swap CHA (CNB#8) with CHB (CNB#7). If ENC SPEED is not close to FREQUENCY, the encoder resolution is wrong and a different SW is needed (see 12.4.7.12 and 12.4.7.8).
- Step8** If the motor runs well without glitches, it is possible to stays with ENCODER CONTROL to OFF; otherwise, turn ENCODER CONTROL to ON.
- Step9** Verify the steered wheel rotates in the correct direction according to the hand wheel. If it isn't, swap CPOC1 (CNA#9) with CPOC2 (CNA#8).
- Step10** Set the LIMIT DEVICE option to OFF to avoid the maximum angle limitations.
- Step11** Set NUMBNESS parameters to Level 0.
- Step12** Move the hand wheel until the maximum (plus 90 degrees) steered wheel angle is achieved (Increase 1ST ANGLE COARSE - and FINE - if necessary). This position (plus 90 degrees) corresponds to the maximum value of the FEEDBACK POT reading in the TESTER menu.
- Step13** With the steered wheel in the maximum angle (plus 90 degrees), enter and save the adjustment SET MAX FB POT on the hand set to memorize the steer angle feedback pot voltage for the maximum (plus 90 degrees) limit position. If present, the maximum of the FB ENC is recorded too (although it is not shown in the hand set).
- Step14** Move the steering wheel until the minimum (minus 90 degrees) steered wheel angle is achieved (Increase 2ND ANGLE COARSE - and FINE - if necessary). This position (minus 90 degrees) corresponds to the minimum value of the FEEDBACK POT reading in the TESTER menu.
- Step15** With the steered wheel in the minimum angle (minus 90 degrees), enter and save the adjustment SET MIN FB POT on the hand set to memorize the steer angle feedback pot voltage for the minimum (minus 90 degrees) limit

position. If present, the minimum of the FB ENC is recorded too (although it is not shown in the hand set).

- Step16** Set FEEDBACK DEVICE to OPTION#3 (feedback pot, feedback encoder and straight ahead toggle switch) and recycle the key to enable the steering by encoder.
- Step17** When FEEDBACK DEVICE is OPTION #3, it is necessary to seek a falling edge on the SW1 (CNA#3) corresponding at the straight ahead position. This is done by moving the steered wheel toward a falling edge of the straight ahead switch. Depending by the shape of the iron plate to act the straight ahead sensor, the falling edge may occur either in a CW or in a CCW rotation. If the iron plate in your arrangement generates a sole rising edge in present steering direction, it is possible to reverse the turning direction of the steered wheel during the initial alignment. To do that an OPTIONS called POT UP SW1 EDGE is supplied. When it is ON, the steered wheel seeks the falling edge during an initial automatic rotation in the direction of an increasing FB POT. When it is OFF, the steered wheel seeks the falling edge during an initial automatic rotation in the direction of a decreasing FB POT. (A properly setting of POT UP SW1 EDGE is required to avoid EPS NOT ALIGN alarm).
- Step18** When FEEDBACK DEVICE is OPTION #3, it is necessary to autoacquire the FB POT value at the matching with the falling edge on the straight ahead switch (SW1). To do that, enter the SET FBPOT AT SW1 setting in the adjustments menu. Save and recycle the key. After the acquisition, the SET FBPOT AT SW1 value should be close to the 2.5 V value; otherwise it is necessary to re-make the FB POT mounting in such a way its wiper is close to 2.5 V at the matching with the falling edge on SW1.
- Step19** Carry out the complete set-up procedure (see 11.1).

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### 10.3 Stepper Motor with Encoder and Feedback pot: one shot installation procedure

This procedure is relative to the connecting drawings Figure 6-2. It describes the step by step installation procedure to get the prototype working in manual mode: to raise the AUTC function it is necessary to make the complete set-up procedure (see topic 11).

For every truck released on the field, the default set-up shall reply the prototype settings and so no installation procedure is required except for the acquisition of the limiting position (see the quick set-up 11.2).

Carry out the procedure in the following order.

- Step1** Connect the AC motor phases in such a way the phase references U, V, W on the steering motor correspond to the terminals references (U, V, W) on the eps-ac0.
- Step2** In the SET MODEL menu set the SYSTEM CONFIG setting to LEVEL 0 to steer in open loop with a stepper motor in manual mode. Turn off and on the key in order the setting is acquired.
- Step3** Set the FEEDBACK DEVICE to OPTION #1 to specify your feedback solution is the sole FEEDBACK POT. Switch off the key after the change. (It is necessary to start with the sole feedback pot to avoid a POSITION ERROR due to the unknown scaling between the encoder counting and the feedback pot value before of an encoder learning operation - Step 12 and 14 below).
- Step4** Set option ENCODER CONTROL to OFF.

- Step5** Connect the feedback pot in such a way the FEEDBACK POT reading in the tester menu assumes higher voltage when the FREQUENCY in the tester menu is positive. When a FB POT LOCKED alarm occurs immediately after switching on the key, it means the motor is turning away from the wished position (i.e. FEEDBACK POT decreases when the FREQUENCY is positive). Then it is necessary to swap the PPOT with NPOT (CNB#2 with CNB#1).
- Step6** Connect the encoder. The encoder supply is between CNB#4 (5 Vdc) and CNA#11 (GND): the two channels are CNB#8 (CHA) and CNB#7 (CHB).
- Step7** Verify the reading ENC SPEED in the tester menu is consistent with the reading FREQUENCY in the tester menu. Consistent means that ENC SPEED and FREQUENCY must have the same sign and a close value. If ENC SPEED has a wrong sign, swap CHA (CNB#8) with CHB (CNB#7). If ENC SPEED is not close to FREQUENCY, the encoder resolution is wrong and a different SW is needed (see 12.4.7.12 and 12.4.7.8).
- Step8** If the motor runs well without glitches, it is possible to stays with ENCODER CONTROL to OFF; otherwise, turn ENCODER CONTROL to ON.
- Step9** Verify the steered wheel rotates in the correct direction according to the hand wheel. If it isn't, swap DL (CNA#9) with QL (CNA#8).
- Step10** Set the LIMIT DEVICE option to OFF to avoid the maximum angle limitations.
- Step11** Turn the steering wheel until the maximum (plus 90 degrees) steered wheel angle is achieved. This position (plus 90 degrees) corresponds to the maximum value of the FEEDBACK POT reading in the TESTER menu.
- Step12** With the steered wheel in the maximum angle (plus 90 degrees), enter and save the adjustment SET MAX FB POT on the hand set to memorize the steer angle feedback pot voltage for the maximum (plus 90 degrees) limit position. If present, the maximum of the FB ENC is recorded too (although it is not shown in the hand set).
- Step13** Turn the steering wheel until the minimum (minus 90 degrees) steered wheel angle is achieved. This position (minus 90 degrees) corresponds to the minimum value of the FEEDBACK POT reading in the TESTER menu.
- Step14** With the steered wheel in the minimum angle (minus 90 degrees), enter and save the adjustment SET MIN FB POT on the hand set to memorize the steer angle feedback pot voltage for the minimum (minus 90 degrees) limit position. If present, the minimum of the FB ENC is recorded too (although it is not shown in the hand set).
- Step15** Set FEEDBACK DEVICE to OPTION#2 (feedback pot plus feedback encoder) and recycle the key to enable the steering by encoder.
- Step16** Carry out the complete set-up procedure (see 11.1).

---

## 10.4 Stepper Motor with Encoder and Toggle Switch(es): one shot installation procedure

This procedure is relative to the connecting drawings Figure 6-2. It describes the step by step installation procedure to get the prototype working in manual mode: to raise the AUTC function it is necessary to make the complete set-up procedure (see topic 11).

For every truck released on the field, the default set-up and wiring shall reply the prototype settings and so no installation procedure is required except for the acquisition of the limiting position (see the quick set-up 11.2). Carry out the procedure in the following order.

- Step1** Connect the AC motor phases in such a way the phase references U, V, W on the steering motor correspond to the terminals references (U, V, W) on the eps-ac0.
- Step2** In the SET MODEL menu set the SYSTEM CONFIG setting to LEVEL 0 to steer in open loop with a stepper motor in manual mode. Turn off and on the key in order the setting is acquired.
- Step3** Set the FEEDBACK DEVICE to OPTION #4 to specify your feedback solution is the encoder with one or two toggle switches. Switch off the key after the change.
- Step4** Turn the special adjustment DEBUG OUTPUT to Level 11 to inhibit the alarm POSITION ERROR and recycle the key.
- Step4** Set option ENCODER CONTROL to OFF.
- Step5** Connect the encoder. The encoder supply is between CNB#4 (5 Vdc) and CNA#11 (GND): the two channels are CNB#8 (CHA) and CNB#7 (CHB).
- Step6** Verify the reading ENC SPEED in the tester menu is consistent with the reading FREQUENCY in the tester menu. Consistent means that ENC SPEED and FREQUENCY must have the same sign and a close value. If ENC SPEED has a wrong sign, swap CHA (CNB#8 with CHB (CNB#7). If ENC SPEED is not close to FREQUENCY, the encoder resolution is wrong and a different SW is needed (see 12.4.7.12 and 12.4.7.8).
- Step7** If the motor runs well without glitches, it is possible to stays with ENCODER CONTROL to OFF; otherwise, turn ENCODER CONTROL to ON.
- Step8** Verify the steered wheel rotates in the correct direction according to the hand wheel. If it isn't, swap DL (CNA#9) with QL (CNA#8).
- Step9** Set the LIMIT DEVICE option to OFF to avoid the maximum angle limitations.
- Step10** Detect the encoder counting corresponding to a steered wheel revolution. To do that, turn the steered wheel some revolutions in CW direction and read the ENC COUNT AT 360 in the tester menu. At every falling edge of the CNA#3 toggle switch (SW1), this reading is updated. It corresponds to the encoder counting for a complete revolution of the steered wheel. ENC COUNT AT 360 shows real time the encoder counting between two consecutive falling edges on the straight ahead toggle switch. The reading is scaled in the range 0 to  $\pm 5$  V.  
 5 V corresponds to an encoder counting of  $2^{15}$  events.  
 -5 V corresponds to an encoder counting of  $-2^{15}$  events.  
 To be sure the shown value is correct, turn the steered wheel some revolutions in the opposite direction. I expect the reading ENC COUNT AT 360 gets the same value but with opposite sign.
- Step11** Enter and save the adjustment SET ENC AT 360. The absolute value in the reading ENC COUNT AT 360 will be recorded on SET ENC AT 360.
- Step12** Recycle the key and turn the steered wheel to get the WHEEL ANGLE reading in the tester menu close to 0 degrees.
- Step13** Check the orientation of the steered wheel in the position having WHEEL ANGLE close to 0. If the steered wheel has not the wished orientation change AUX FUNCTION 11. If AUX FUNCTION 11 is set to Level 5, it is necessary to change to Level 4 or vice versa. If AUX FUNCTION 11 is set to Level 2, it is necessary to change to Level 3 or vice versa.
- Step14** Recycle the key. Now, when WHEEL ANGLE is null, the steered wheel must be oriented in the wished direction.
- Step15** Turn the steered wheel to have the reading WHEEL ANGLE close to +45 degrees (first sector). Read the ENDSTROKE CW and ENDSTROKE ACW in the tester menu. Set AUX FUNCTION 11 to the proper level as specified below:  
 ENDSTROKE CW=OFF and ENDSTROKE ACW=OFF: Level 2

ENDSTROKE CW=OFF and ENDSTROKE ACW=ON: Level 3  
 ENDSTROKE CW=ON and ENDSTROKE ACW=OFF: Level 4  
 ENDSTROKE CW=ON and ENDSTROKE ACW=ON: Level 5

This setting is necessary to match the WHEEL ANGLE measurement (calculated through the encoder counting) with the sector determined with the toggle switches configuration (POSITION ERROR alarm in case of mismatching).

Table 10-1 below shows the correct setting for AUX FUNCTION 11 vs. the toggle switches configuration in the first sector (WHEEL ANGLE inside the range 0 to 90 degrees).

<b>AUX FUNCTION 11</b>	<b>Toggle sw number</b>	<b>SW1 to CNA#3</b>	<b>SW2 to CNA#2</b>
Level 0	1	H	NC
Level 1	1	L	NC
Level 2	2	H	H
Level 3	2	H	L
Level 4	2	L	H
Level 5	2	L	L

Table 10-1

- Step16** Option AUTOCENTERING enables the automatic alignment at key-on together with the automatic centering operations.
- Step17** Option ORIENT THE WHEEL is used only when AUTOCENTERING is ON to specify the steered wheel orientation at the initial automatic alignment. It gets the steered wheel oriented at the straight ahead position (null WHEEL ANGLE) or to the 180 degrees position (depending by this setting).
- Step18** Parameters 1ST ANGLE COARSE and 2ND ANGLE COARSE set the maximum steered wheel angle respectively in the positive and negative WHEEL ANGLE. Set both of them to level 9 to avoid angle limitation. Lower setting limits the maximum angle in the range 80 degrees + Level\*4degrees (e.g. Level 0 means limitation to 80 deg; Level 1 means limitation to 84 deg and so on).
- Step19** If there is not angle limitation, a refreshing of the steered wheel position is made on every edge of the CNA#3 straight ahead toggle switch provided that the absolute value of WHEEL ANGLE is less than 30 degrees. That mean the refreshing is performed for every edge of the straight ahead switch but only once per steered wheel revolution.  
 If the angle is limited, a refreshing of the steered wheel position is made on every falling edge of the CNA#3. In the worst case a refresh is performed every 360 degrees.
- Step20** Don't forget to turn the special adjustment DEBUG OUTPUT to level 15 after finished the setting procedure to enable the POSITION ERROR test between encoder counting and toggle switches sector. Recycle the key.
- Step21** Carry out the complete set-up procedure (see 11.1).

# 11 SETTING THE EPS-AC0

## 11.1 Complete set-up description

This procedure shall be executed on the prototype after the installation procedure is completed (see topic 10). The complete set-up changes vs. the truck configuration. Seek your own configuration below:

### 11.1.1 Stepper Motor only

- Step1** Set the SET SAT FREQ adjustment to the corner frequency of the steering motor (see 12.4.2.7).
- Step2** Set OVERSAT FREQ adjustment in order the sum between SET SAT FREQ and OVERSAT FREQ gives the wished maximum steering motor speed (see 12.4.2.8).
- Step3** Set the NO LOAD CURRENT adjustments to the current the motor drains when lightened at the maximum flux (see 12.4.2.10).
- Step4** Set the steer sensitivity with the SPEED LIMIT and SENSITIVITY parameters (see 12.4.4.1-2).
- Step5** Set AUTO REQ TYPE in the set model menu to level 0 (no automatic function). (See 12.4.3.2).
- Step6** (CAN Based system only). Set the Dynamic Numbness in open loop (steering sensitivity reduces when the truck speed increases). Use parameters AUX FUNCTION#2 and AUX FUNCTION #3 (see 12.4.4.5-4).
- Step7** (No CAN Based system only). Connect a traction travel demand to CNA#1. It can be a tiller switch (or a dead-man or a seat switch). This operation supplies the information the truck is moving or not to stand-by the steer when the truck is standing.

### 11.1.2 Stepper Motor & AUTC

When the AUTC is required, it is necessary to carry out all the Steps in paragraph 11.1.1 together with the following:

- Step1** When the autocentering (AUTC) is required, it is necessary to contact a Zapi technician to decide the physical and the superior protocol layers for the AUTC demanding. (AUTC is a customized function that the eps-ac0 does not execute in its standard version).  
One possible arrangement for the AUTC request could be a via CAN bus demanded centering.
- Step2** Turn the truck in the automatic centering mode, drive the truck and roll up and down the adjustment SET STEER 0-POS until the truck is straight travelling.
- Step3** Set the parameters KP, POS. ACCURACY, LEAD FB REGULAT and LAG FB REGULAT to avoid overshoot or damping during the centering operation (see paragraph 12.4.4).

### 11.1.3 RTC (Twin Pot) only

- Step1** Set the SET SAT FREQ adjustment to the corner frequency of the steering motor (see 12.4.2.7).
- Step2** Set OVERSAT FREQ adjustment in order the sum between SET SAT FREQ and OVERSAT FREQ gives the wished maximum steering motor speed (see 12.4.2.8).

- Step3** Set the NO LOAD CURRENT adjustments to the current the motor drains when lightened at the maximum flux (see 12.4.2.10).
- Step4** Leave the handle steer in its straight position. Enter and Save the adjustment ZERO SP POT (see 12.4.2.16). This operation is used to automatically learn the twin pot voltage.
- Step5** Set AUTO REQ TYPE in the set model menu to level 0 (no automatic function).
- Step6** Leave the handle steer in its straight position. Drive the truck and roll up and down the adjustment SET STEER 0-POS until the truck is straight travelling.
- Step7** Set 1ST ANGLE COARSE (and FINE) to get the steered wheel position limited at +90 degrees when the SET POINT POT reading is maximum. This is the direction where the FEEDBACK ENC reading is higher than 2.5 Vdc.
- Step8** Set 2ND ANGLE COARSE (and FINE) to get the steered wheel position limited at -90 degrees when the SET POINT POT reading is minimum. This is the direction where the FEEDBACK ENC reading is lower than 2.5 Vdc.
- Step9** Try to adjust the NUMBNESS parameter to get the steer less sensitive when close to the straight ahead direction (see 12.4.4.17). (For every new NUMBNESS value, repeat the above Step7 and Step8).
- Step10** Try different settings for KP, POS. ACCURACY, LEAD FB REGULAT and LAG FB REGULAT to avoid overshoot or damping during the pursuing operation (see paragraph 12.4.4).
- Step11** (CAN Based system only). Set the Dynamic Numbness in closed loop (steering sensitivity reduces when the truck speed increases). The parameters to handle this function are AUX FUNCTION#2 and AUX FUNCTION #3 (see 12.4.4.5-4).
- Step12** (No CAN Based system only). Connect a traction travel demand to CNA#1. It can be a tiller switch (or a dead-man or a seat switch). This operation supplies the information the truck is moving or not to stand-by the steer when the truck is standing.

### 11.1.4 RTC & AUTC

When the AUTC is required, it is necessary to carry out all the Steps in paragraph 11.1.3 together with the following:

- Step1** When the autocentering (AUTC) is required, it is necessary to contact a Zapi technician to decide the physical and the superior protocol layers for the AUTC demanding. (AUTC is a customized function that the eps-ac0 does not execute in its standard version).  
One possible arrangement for the AUTC request could be a via CAN bus demanded centering.

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## 11.2 Quick set-up

This procedure shall be executed on every manufactured truck. It changes with the configuration. We assume the default setting includes the correct value for SET ENC AT 360 in a configuration with feedback enc and toggle switches. When a configuration with the feedback pot is adopted, step 11 to step 15 in paragraph 10.3 are required too (acquisition of the limits).

### 11.2.1 Stepper Motor only

No set-up required on a truck working open loop (stepper motor) in manual mode only.

### 11.2.2 Stepper Motor & AUTC

When the Automatic Centering (AUTC) is required on a truck working open loop in manual mode (stepper motor), it is necessary to guide the truck in automatic mode and to perform the following steps:

**Step1** Roll-up or down the adjustments SET STEER 0-POS to get the truck straight travelling when automatic centered.

### 11.2.3 RTC only or RTC & AUTC

In a truck working closed loop in manual mode (with a Twin Pot connected on the Return To Center handlebar) with or without the AUTC function, it is necessary to perform the following steps:

**Step1** Release the handlebar in its straight-ahead rest position and acquire the adjustments ZERO SP POT (to record the rest twin pot voltage).

**Step2** Roll-up or down the adjustments SET STEER 0-POS to get the truck straight travelling when the handlebar is straight ahead.

# 12 PROGRAMMAING & ADJUSTMENTS USING DIGITAL CONSOLE

## 12.1 Adjustments via console

Adjustment of Parameters and changes to the inverter's configuration are made using the Digital Console. The Console is connected to the CNC connector of the inverter.

## 12.2 Description of console (hand set) & connection

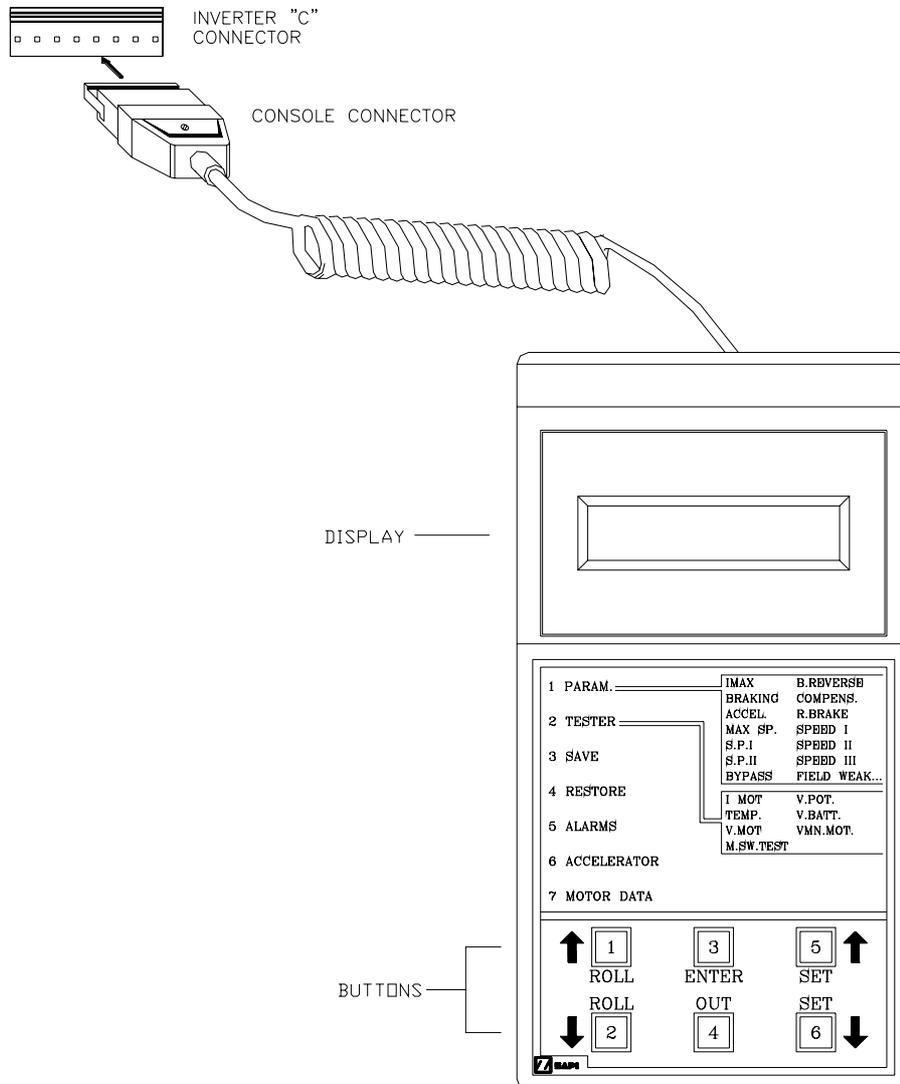


Figure 12-1

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## 12.3 Description of standard console menu

Digital consoles used to communicate with AC inverter controllers must be fitted with EPROM CK ULTRA, minimum "Release Number 3.02".

The section describes the Zapi hand set functions. Numbers inside the triangles correspond to the same number on the hand set keyboard buttons shown in the Figure 12-1. The orientation of the triangle indicates the way to the next function.

### 12.3.1 Stepper motor with Encoder and Feedback pot

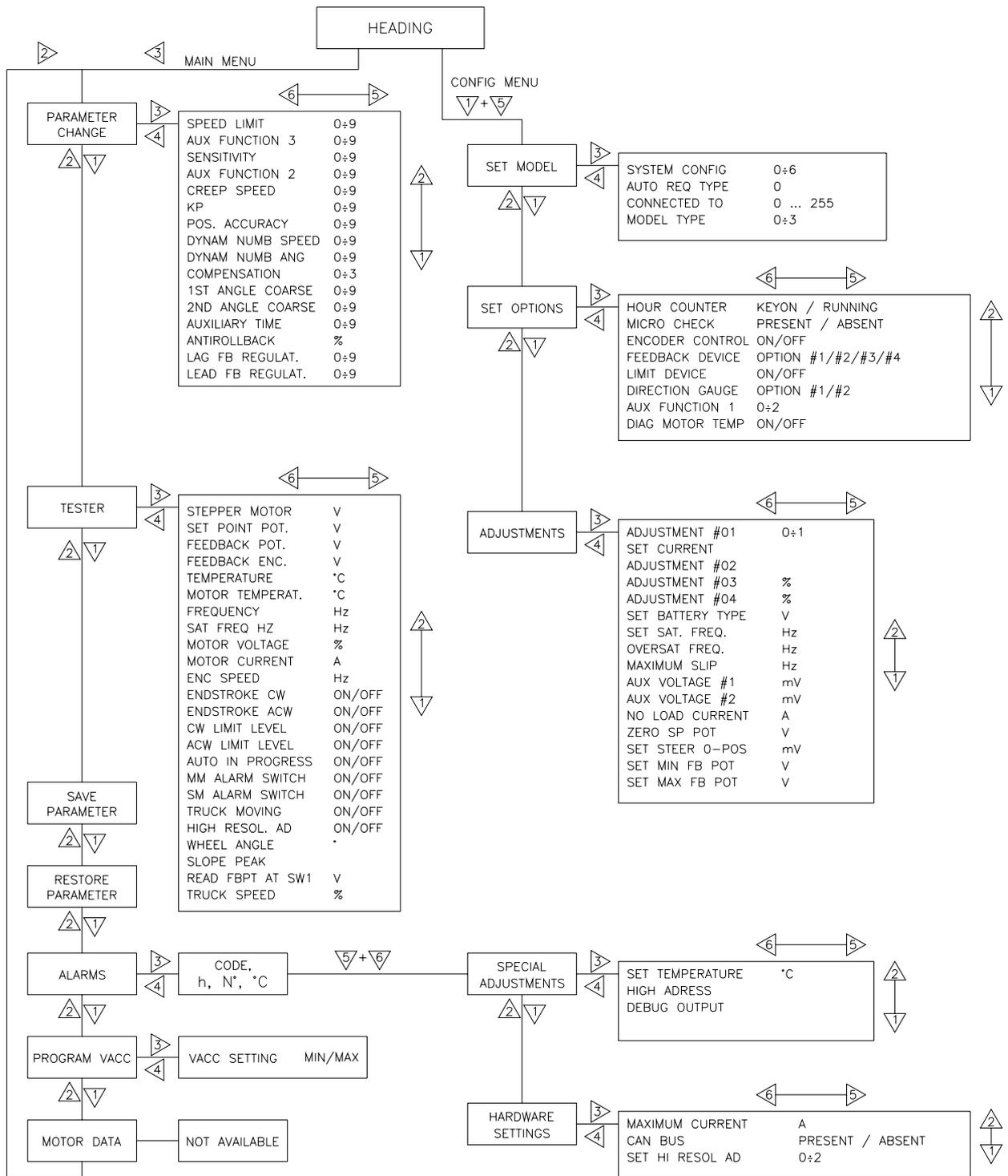


Figure 12-2

### 12.3.2 RTC with Encoder and Feedback pot

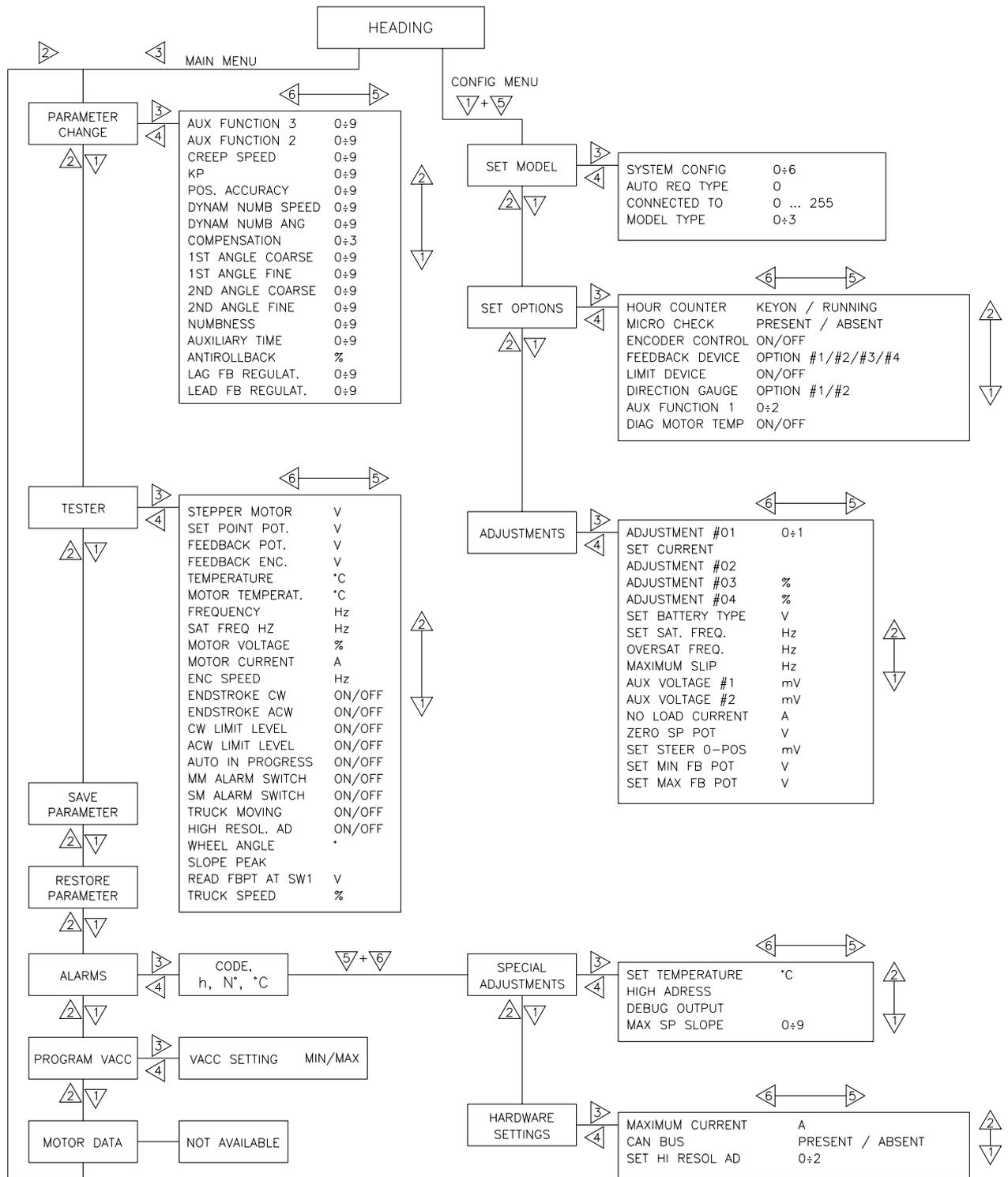


Figure 12-3

### 12.3.3 Stepper motor with Encoder and Toggle switch(es)

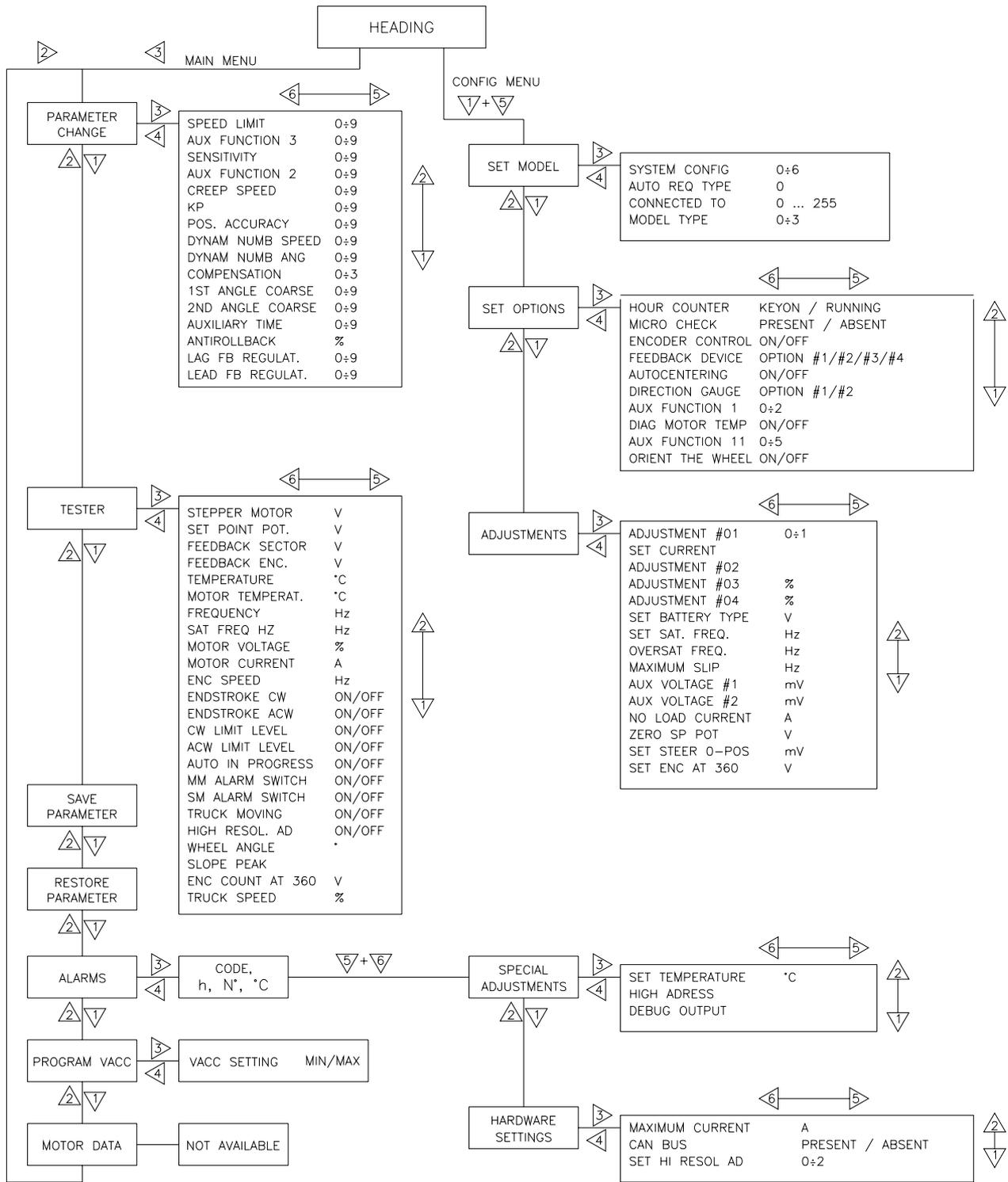


Figure 12-4

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## 12.4 Function configuration

The functions list change with the settings SYSTEM CONFIG and FEEDBACK DEVICE (see 12.4.3.1 and 12.4.1.3). In particular, we will distinguish between the configuration with stepper motor against the one with RTC in the hand wheel: besides we distinguish between the configuration with the encoder plus toggle switches against the one with the encoder plus potentiometer as feedback sensor. In the next we refer to a complete list that is the union of the settings in the above configurations. When the setting refers to only one configuration, it will be specified in the description.

### 12.4.1 Config menu “SET OPTIONS” functions list

To enter the CONFIG MENU it is necessary to push in the same time the right side top and left side top buttons. Then roll until the SET OPTION item appears on the hand set display. Push the ENTER button (see Figure 12-5).



Figure 12-5

### 1) HOUR COUNTER

This option specifies the hour counter mode. It can be set one of two:

- RUNNING: The counter registers travel time only.
- KEY ON: The counter registers when the "key" switch is closed.

### 2) MICRO CHECK

This option is useful to support debug and troubleshooting. It makes possible to inhibit the supervisor (Slave uC) operations and allows the system to run with just the Main uC. When entering this operating mode the safety contacts stay open. Therefore, traction shall be disabled. It can be set one of two:

- PRESENT: Default setting: enable the operations of the supervisor (Slave uC).
- ABSENT: Disable the operations of the supervisor (Slave uC). The safety contacts stay opened.

### 3) FEEDBACK DEVICE

This option specifies which kind of Feedback Sensor is adopted. Here is the feedback sensor list:

- OPTION #1: FB POT only.  
The only feedback sensor is the potentiometer at the steered wheel. This setting must be temporary chosen for the set-up of the FB ENC & FB POT configuration (see below). After the set-up is ended, it is necessary to turn FEEDBACK DEVICE to OPTION #2 to get the steer working with FB ENC & FB POT.
- OPTION #2: FB POT & FB ENC.  
This is the right setting when the encoder is chosen together with the FB POT. Pay attention, the set-up must be done with the FEEDBACK DEVICE to OPTION #1. When the set-up is finished, turn to OPTION #2. When the FEEDBACK DEVICE is OPTION #2 an automatic centering is always carried out at key-on.
- OPTION #3: FB POT & FB ENC & ONE TOGGLE SWITCH  
This is the right setting when the encoder is chosen together with the FB POT and a straight ahead toggle switch (SW1). Pay attention, the set-up must be done with the FEEDBACK DEVICE to OPTION #1. When the set-up is finished, turn to OPTION #3. When the FEEDBACK DEVICE is OPTION #3 an automatic centering is always carried out at key-on.
- OPTION #4: FB ENC & ONE (or TWO) TOGGLE SWITCHES  
This is the right setting when the FB POT is not present and two toggle switches are adopted (normally in the straight and 90 degrees angled positions of the steered wheel). At key on, an Automatic Centering operation is executed seeking the Toggle Switch signal (SW1 on CNA#3). When the Toggle Switch edge is met the Encoder counter is zeroed. The 2<sup>nd</sup> Switch (SW2 on CNA#2) is used to verify the encoder counter at 90° is matched with the SW2 transition.

### 4) LIMIT DEVICE

(Versions with FEEDBACK DEVICE to OPTION #1, 2, 3 only). When this option is set ON, the steered wheel angle will be limited using the feedback sensor value. It can be set one of two:

- ON: When the feedback sensor overtakes either the CW or the CCW limit (see 12.4.2.13-14, SET MAX FB POT, SET MIN

FB POT), the steered wheel angle shall be automatically limited.

- OFF: No steered wheel angle limitation, based on the feedback sensor value, occurs.

Note: the configurations without toggle switches (FB POT only and FB POT & FB ENC) may use the switches connected to CNA#3 and CNA#2 as CW and CCW limiting requests. Then, the limitation through the feedback device and the limitation through the limiting switches are processed with an OR Logic.

#### 5) **AUTOCENTERING**

(Versions with FEEDBACK DEVICE to OPTION #4 only). When this option is set ON, the controller performs an automatic centering at key-on and enables the function to operate an automatic centering on demand. Set AUTOCENTERING to OFF if the automatic centering function is not required.

#### 6) **DIRECTION GAUGE**

Not used.

#### 7) **AUX FUNCTION 1**

This option sets the steering mode after the feedback sensor has reached the commanded position (it is used only in closed loop configurations (i.e. RTC and automatic centering)). It can be set one of three:

- LEVEL 0: The steering control is always active when a travel demand is active. The steer control is turned off when the travel demands are deactivated (after a 3 sec delay).
- LEVEL 1: The steering control is alternatively turned off (15 secs long plus the AUXILIARY TIME) and on (3 secs long).
- LEVEL 2: The steering control is alternatively turned off (15 secs long plus the AUXILIARY TIME) and on (3 secs long) but only when a travel demand is active.

AUXILIARY TIME is the delay (in secs) the DC standing current takes to arrive to 0 (see 12.4.4.11).

#### 8) **DIAG MOTOR TEMP**

This option enables the diagnosis of the motor temperature. When it is set On and the motor temperature overtakes 150°, a MOTOR TEMPERAT alarm occurs.

The KTY84-130 motor thermal sensor must be connected between CNB#3 and a minus battery (CNA#13).

#### 9) **AUX FUNCTION 11**

(only when FEEDBACK DEVICE is OPTION #4). Option AUX FUNCTION 11 specifies the number of toggle switches (one or two) and defines the correspondence between the levels of the toggle switches and the steer sector (quadrant).

Set AUX FUNCTION 11 to the proper Level following table 10-1 (see 10.4). The proper level must be meant as the one meeting the configuration of the toggle switches in the first sector (WHEEL ANGLE between 0 and 90 degrees).

#### 10) **ENCODER CONTROL**

This option specifies if the motor is controlled via encoder or completely sensorless. Normally it is set OFF. When glitches are heard from the motor, it is necessary to turn to a sensed control. In this case set ENCODER CONTROL to On. Then, take care the encoder resolution used in the software (see 4.5.3) is

matched with the actual encoder resolution.

#### **11) ORIENT THE WHEEL**

(only when FEEDBACK DEVICE is OPTION #4). Option ORIENT THE WHEEL is used only when AUTOCENTERING is ON to specify the steered wheel orientation at the initial automatic alignment. It gets the steered wheel oriented at the straight ahead position (null WHEEL ANGLE) or to the 180 degrees position (depending by this setting).

#### **12) POT UP SW1 EDGE**

(only when FEEDBACK DEVICE is OPTION #3). It is possible to reverse the turning direction of the steered wheel during the initial alignment. To do that an OPTIONS called POT UP SW1 EDGE is supplied. When it is ON, the steered wheel seeks the falling edge during an initial automatic rotation in the direction of an increasing FB POT. When it is OFF, the steered wheel seeks the falling edge during an initial automatic rotation in the direction of a decreasing FB POT. (A properly setting of POT UP SW1 EDGE is required to avoid EPS NOT ALIGN alarm).

## 12.4.2 Config menu “ADJUSTMENTS” functions list

To enter the CONFIG MENU it is necessary to push in the same time the right side top and left side top buttons. Then roll until the ADJUSTMENTS item appears on the hand set display. Push the ENTER button (see the Figure 12-6 below).

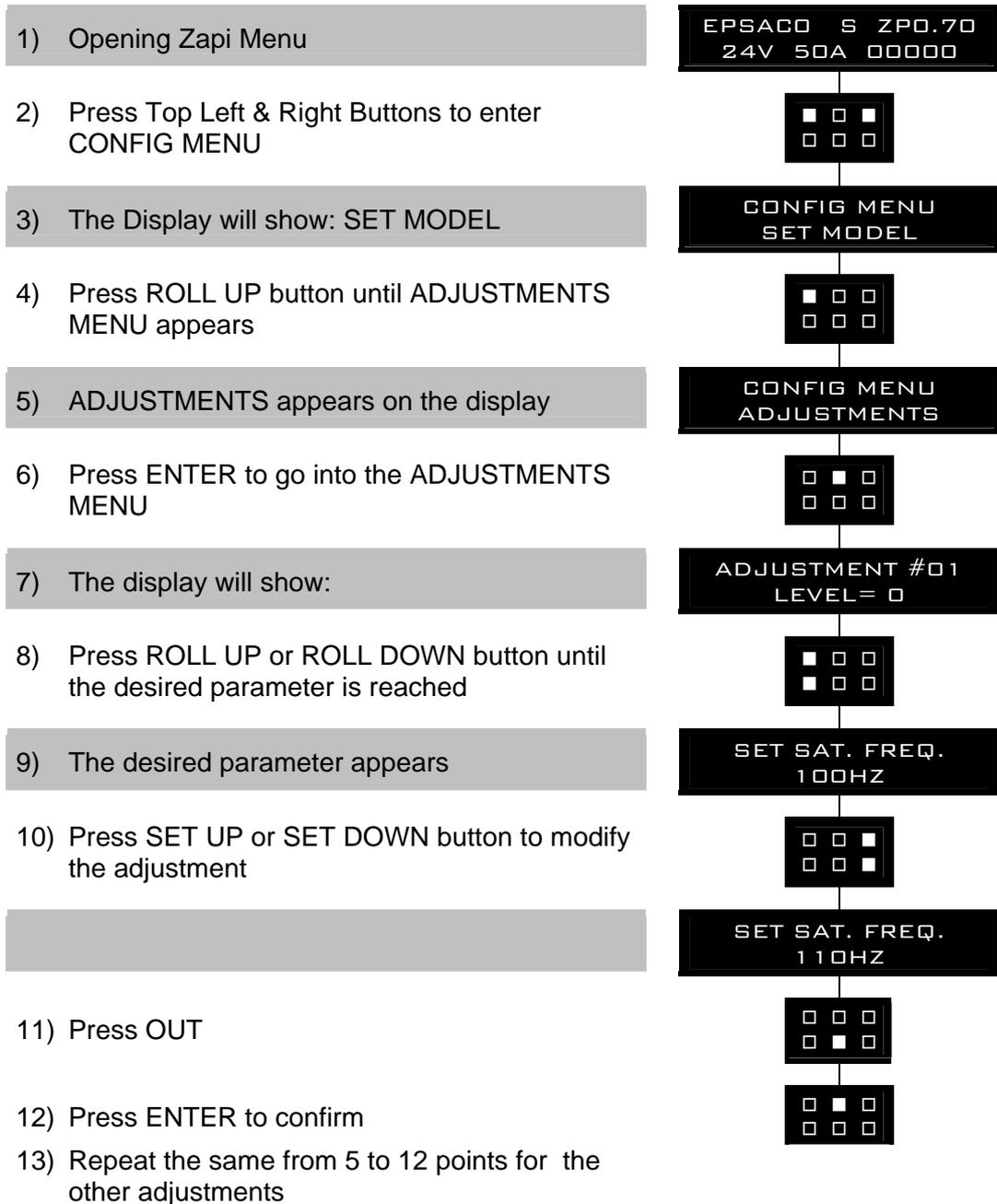


Figure 12-6

- 1) **ADJUSTMENT #01**  
This setting is used to acquire the motor resistance (see 13.1).
- 2) **SET CURRENT**  
This setting is factory adjusted to calibrate the ADJUSTMENT #03 and #04 below.
- 3) **ADJUSTMENT #02**  
Motor resistance in milliohms. This is the resistance of the motor measured between two motor terminals. The motor resistance may be either self-acquired with the procedure 13.1 or may be set by rolling up or down this adjustment.
- 4) **ADJUSTMENT #03**  
(Factory adjusted). Parameter to compensate for the gain of the current amplifier in phase W.
- 5) **ADJUSTMENT #04**  
(Factory adjusted). Parameter to compensate for the gain of the current amplifier in phase V.
- 6) **SET BATTERY TYPE**  
Set this adjustment to the nominal battery voltage. Pay attention, never set SET BATTERY TYPE higher than 36 V for a 24/36 V controller.
- 7) **SET SAT. FREQ.**  
Set this adjustment to the corner frequency of the motor. SET SAT FREQ is to be meant as the maximum frequency at which the motor supplies the maximum torque (it is the superior limit of the constant torque characteristic). Frequency higher than SET SAT FREQUENCY gets the motor weakened.
- 8) **OVERSAT FREQ**  
The maximum motor frequency is set with the sum between SET SAT FREQ and OVERSAT FREQ. OVERSAT FREQ is the increment, over the SET SAT FREQUENCY, in which the steering motor works with degraded flux (weakening area). Default choice is 1 Hz (i.e. the steering motor never works in the weakening region).
- 9) **MAXIMUM SLIP**  
(Factory adjusted). MAXIMUM SLIP modifies the acceleration and deceleration ramp for the frequency in the motor. Higher MAXIMUM SLIP gets faster acceleration and deceleration ramp.  
If the encoder is used for the motor control (ENCODER CONTROL is On), MAXIMUM SLIP has another meaning: it is the slip to be applied when the control is sourcing the maximum current.
- 10) **NO LOAD CURRENT**  
In order it shall be possible to weaken the steering motor when lightened (reducing power loss in the motor), it is necessary to specify the current the motor drains when working full flux and without load (NO LOAD CURRENT). To find this value it is necessary to set the DEBUG OUTPUT to level 10 (see 12.4.6.4) and to measure the current in the motor when running without load and a frequency close to SET SAT FREQ/2.
- 11) **AUX VOLTAGE #1**  
(Factory adjusted). This is the self-acquired offset value of the stepper motor line connected to CNA#9. The default value is 2.500 mV and can be re-acquired

by rolling the DEBUG OUTPUT to 0 (see 12.4.6.4).

**12) AUX VOLTAGE #2**

(Factory adjusted). This is the self-acquired offset value of the stepper motor line connected to CNA#8. The default value is 2.500 mV and can be re-acquired by rolling the DEBUG OUTPUT to 0 (see 12.4.6.4).

**13) SET MIN FB POT**

(Versions with FB POT only). This adjustment is used to self-acquire (see 10.3 and 10.4) the feedback pot value and the encoder counting corresponds to the limiting position having the FEEDBACK POT reading lower than 2.5V (typically -90 degrees). If the option LIMIT DEVICE is set On, the steered wheel angle will be limited when the FEEDBACK POT reading is lower than SET MIN FB POT value.

**14) SET MAX FB POT**

(Versions with FB POT only). This adjustment is used to self-acquire (see 10.3 and 10.4) the feedback pot value and the encoder counting corresponds to the limiting position having the FEEDBACK POT reading higher than 2.5 V (typically +90 degrees). If the option LIMIT DEVICE is set On, the steered wheel angle will be limited when the FEEDBACK POT reading is higher than SET MAX FB POT value.

**15) SET ENC AT 360**

(Versions with FEEDBACK DEVICE to OPTION #4 only). This adjustment is used to self-acquire (see 10.4) the encoder counting corresponding to a complete steered wheel revolution. It is used in the arrangements using the FB ENC and Toggle switches to properly scale the encoder counting with the steered wheel angle (WHEEL ANGLE).

**16) ZERO SP POT**

(RTC version only). This adjustment is used to self-acquire (see 11.1.3 and 11.2.3) the voltages on the twin potentiometers when the steer handle is released in its straight ahead position. Just push the enter button with a released steer handle to record the new ZERO SP POT value.

**17) SET STEER 0-POS**

Although ZERO SP POT was acquired, it is possible the steer handle is released but the steered wheel is not straight-ahead yet. This offset can be compensated through this adjustment. It must be set to the FEEDBACK ENC value corresponding to a perfectly straight-ahead steered wheel. This setting is used for manual mode RTC and AUTC.  
SET STEER 0-POS may be rolled up or down in 5 mV steps.

**18) SET FBPOT AT SW1**

(Versions with FEEDBACK DEVICE to OPTION #3 only). Reading READ FBPT AT SW1 provides the FB POT value at the initial matching with the falling edge on the straight ahead switch (SW1). By entering adjustment SET FBPOT AT SW1, its value changes to the value of reading READ FBPOT AT SW1 (i.e. the READ FBPO AT SW1 is recorded on SET FBPOT AT SW1). In normal condition, reading READ FBPT AT SW1 is expected to reply the SET FBPOT AT SW1 value. When a displacement exists between these two values, a POSITION ERROR alarm may occur (see 14.1.3.5).

### 12.4.3 Config menu “SET MODEL” functions list

To enter the CONFIG MENU it is necessary to push in the same time the right side top and left side top buttons. Then roll until the SET MODEL item appears on the hand set display. Push the ENTER button (see the Figure 12-7 below).

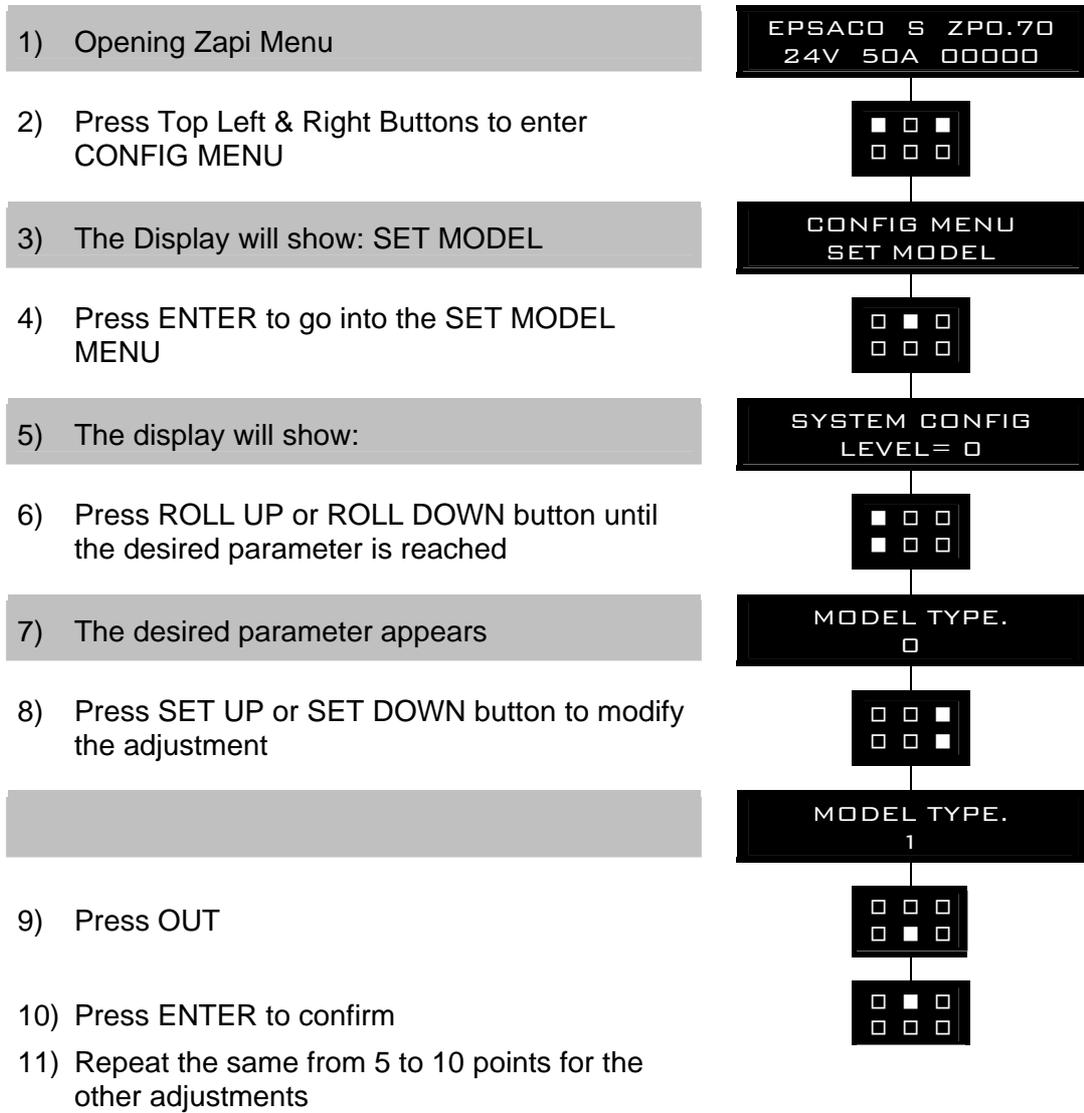


Figure 12-7

## 1) SYSTEM CONFIG

Level 0 to 6. This setting is used to select the steer configuration (i.e. the open or closed loop mode and the type of command sensors) in the following combination list.

- LEVEL 0: **Stepper motor with feedback sensor.** This is an open loop configuration. The stepper motor is used as a tachogenerator to supply the wished steering motor speed. The feedback sensor is not strictly necessary in open loop configuration; in spite of that, this setting specifies the feedback sensor is present and it will be used for the automatic function (AUTC), maximum angle limitation, detection of the locked motor and to perform the alignment at the rest position.  
The FEEDBACK DEVICE option (see 12.4.1.3) specifies which kind of feedback sensor is adopted.
- LEVEL 1: **Twin pot with feedback sensor.** This is a closed loop configuration. The twin pot supplies the commanded position for the steered wheel. The feedback sensor is mandatory to close the loop with the commanded position. The twin pot is a double potentiometer with complementary action (see 4.4.2).  
The FEEDBACK DEVICE option (see 12.4.1.3) specifies which kind of feedback sensor is adopted.
- LEVEL 2: **Via CAN demanded-speed with feedback sensor.** This is an open loop configuration. A remote unit provides the wished steering motor speed via CAN Bus. The feedback sensor is not strictly necessary in open loop configuration; in spite of that, this setting specifies the feedback sensor is present and it will be used for the automatic function (AUTC), maximum angle limitation, detection of the locked motor and to perform the alignment at the rest position.  
The FEEDBACK DEVICE option (see 12.4.1.3) specifies which kind of feedback sensor is adopted.
- LEVEL 3: **Via CAN demanded-position with feedback sensor.** This is a closed loop configuration. A remote unit provides the commanded position for the steered wheel via CAN Bus. The feedback sensor is mandatory to close the loop with the commanded position.  
The FEEDBACK DEVICE option (see 12.4.1.3) specifies which kind of feedback sensor is adopted.
- LEVEL 4: **Stepper motor without feedback sensor.** This is an open loop configuration. The stepper motor is used as a tachogenerator to supply the wished steering motor speed. As the feedback sensor is not strictly necessary in open loop mode, it is possible to work without feedback sensor at all. In spite of that, when the maximum angle limitation via feedback sensors is enabled (option LIMIT DEVICE to ON when FEEDBACK DEVICE is OPTION #1,2,3; 1<sup>ST</sup> ANGLE COARSE and 2<sup>ND</sup> ANGLE COARSE less than level 9 when FEEDBACK DEVICE is OPTION #4), the feedback sensor is expected to perform the secondary functions of maximum angle limitation, detection of the locked motor and to perform the alignment at the rest position. When these conditions are met, the FEEDBACK DEVICE option (see 12.4.1.3) specifies which kind of feedback sensor is adopted for the secondary

- functions. With this choice, the automatic functions are inhibited (the AUTC function isn't possible).
- LEVEL 5: **Single pot with feedback sensor.** This is a closed loop configuration. The single pot supplies the commanded position for the steered wheel. The feedback sensor is mandatory to close the loop with the commanded position. This choice is just for testing a prototype before to gather a twin pot; we strongly advice against using this configuration for the field production. The FEEDBACK DEVICE option (see 12.4.1.3) specifies which kind of feedback sensor is adopted.
  - LEVEL 6: **Via CAN demanded speed without feedback sensor.** This is an open loop configuration. A remote unit provides the wished steering motor speed via CAN Bus. As the feedback sensor is not strictly necessary in open loop mode, it is possible to work without feedback sensor at all. In spite of that, when the maximum angle limitation via feedback sensors is enabled (option LIMIT DEVICE to ON when FEEDBACK DEVICE is OPTION #1-2-3; 1<sup>ST</sup> ANGLE COARSE and 2<sup>ND</sup> ANGLE COARSE less than level 9 when FEEDBACK DEVICE is OPTION #4), the feedback sensor is expected to perform the secondary functions of maximum angle limitation, detection of the locked motor and to perform the alignment at the rest position. When these conditions are met, the FEEDBACK DEVICE option (see 12.4.1.3) specifies which kind of feedback sensor is adopted for the secondary functions. With this choice, the automatic functions are inhibited (the AUTC function isn't possible).

In the above list, the configurations with the command via CAN Bus may be developed only if the communication protocol between eps-ac0 and remote unit is known.

## 2) AUTO REQ TYPE

Level 0 to 9. This setting specifies the type of the automatic request. The standard version foresees no automatic function so this setting is ineffective. The only exception is the configuration FEEDBACK DEVICE to OPTION #4 (encoder and toggle switches). Then the automatic centering is regulated with the option AUTOCENTERING (see 12.4.1.5). AUT REQ TYPE will be handled time to time according the automatic function customer's specification.

## 3) CONNECTED TO

It assumes a number between 0 to 255. This setting is used to (virtually) connect the hand-set to a remote unit CAN Bus connected. With the hand-set connected to the eps-ac0 it is possible to communicate with a remote Zapi unit. Every Zapi unit has its own identification number (e.g. eps-ac0 is 6; traction controller is 2; pump controller is 1). By setting CONNECTED TO to 2, the hand set will be virtually connected to the traction controller.

## 4) MODEL TYPE

It assumes a number between 0 to 3. This setting is used to specify which one local elaboration unit must be virtually connected to the hand-set. In fact eps-ac0 has two uCs aboard. When MODEL TYPE is set to 0, the hand set is communicating with the main uC; when MODEL TYPE is set to 1, the hand set is communicating with the slave uC.

### 12.4.4 Main menu “PARAMETER CHANGE” functions list

To enter the MAIN MENU it is just necessary to push the ENTER button from the home display in the hand set.

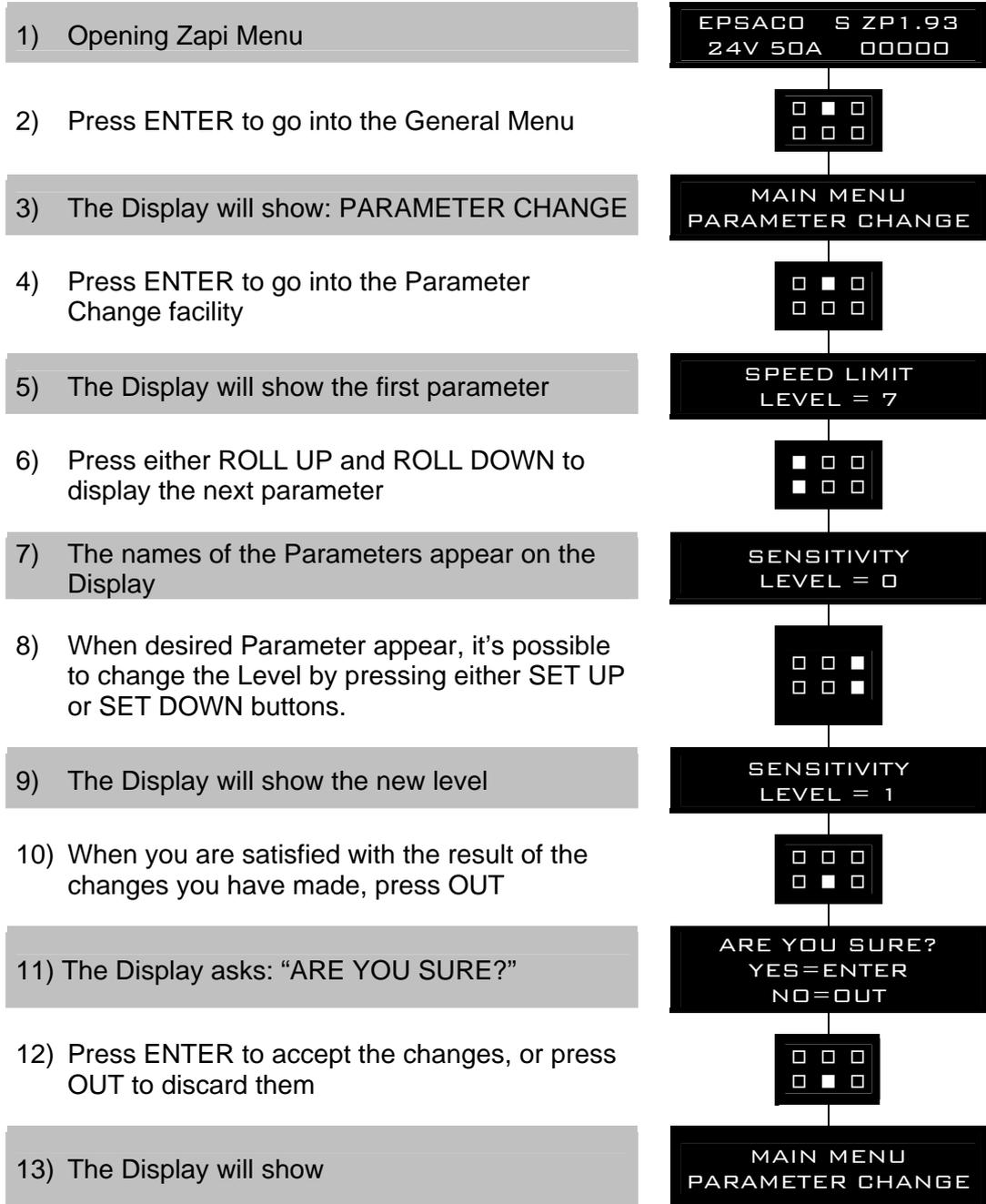


Figure 12–8

- 1) **SPEED LIMIT**  
(Stepper Motor version only). Level 0 to 9. It determines the scaling factor between the speed of the steering wheel and the speed of the steering motor but only when the steering wheel is fast turning. By increasing the SPEED LIMIT value, the steering motor speed increases too. In practice, it sets the maximum motor speed when the steering wheel is fast turning.
- 2) **SENSITIVITY**  
(Stepper Motor version only). Level 0 to 9. It determines the scaling factor between the speed of the steering wheel and the speed of the steering motor but only when the steering wheel is slow turning. By increasing the SENSITIVITY value, the steering motor speed increases too. In practice, it changes the sensitivity of the steering wheel when it is slow turning.
- 3) **CREEP SPEED**  
Level 0 to 9. It sets a minimum amount of motor torque when the steering motor is slow turning. It is useful (together with the ANTIROLLBACK parameter, see 12.4.4.12) to neutralize the recall torque generated by the elastic tyre on the steered wheel.
- 4) **AUX FUNCTION #3**  
Depending on the configuration, this parameter has different meaning.

***RTC version:***

Level 0 to 9. This setting performs the Dynamic Numbness compensation: it consists of a reduction in the steer sensitivity when the truck is driving at high speed. To get this goal, this setting adjusts the maximum angle at full truck speed. When the truck speed increases, the maximum steered wheel angle reduces proportionally. When the truck is full speed the steered wheel angle is limited to a percentage of the absolute maximum steered wheel angle (i.e. 90 degrees) specified with this setting.

- LEVEL 0: Maximum steered angle at full truck speed is 73% (i.e. 66 degrees).
- LEVEL 1: Maximum steered angle at full truck speed is 66% (i.e. 59 degrees).
- LEVEL 2: Maximum steered angle at full truck speed is 59% (i.e. 53 degrees).
- LEVEL 9: Maximum steered angle at full truck speed is 10% (i.e. 9 degrees).

Each step has a weight of 7%.

***Stepper Motor version:***

Level 0 to 9. This setting performs the Dynamic Numbness compensation: it consists of a reduction in the steer sensitivity when the truck is driving at high speed. To get this goal, it is necessary to attenuate the scaling factor between the speed of the steering wheel and the speed of the steering motor. AUX FUNCTION #3 does that but only when the steering wheel is **fast** turning. This attenuation must be proportional to the drive speed. At full drive speed the attenuation of the scaling factor is maximum.

AUX FUNCTION #3 to Level 0 means no attenuation of the scaling factor with the truck speed.

AUX FUNCTION #3 to Level 9 means maximum attenuation of the scaling factor with the truck speed.

Obviously, to perform the Dynamic Numbness compensation, it is necessary to know the drive speed and so the eps-ac0 must be CAN Bus connected.

## 5) AUX FUNCTION #2

Depending on the configuration, this parameter has different meaning.

### **RTC version:**

Level 0 to 9. This setting performs the Dynamic Numbness compensation: it consists of a reduction in the steer sensitivity when the truck is driving at high speed. To get this goal, this setting adjusts the percentage of the maximum truck speed, at which the steered angle reduction will start. Then for higher speed the steered angle reduction increases proportionally up to the above specified limit.

- LEVEL 0: max angle starts to reduce when the truck speed is 1% of the maximum speed.
- LEVEL 1: max angle starts to reduce when the truck speed is 12% of the maximum speed.
- LEVEL 2: max angle starts to reduce when the truck speed is 23% of the maximum speed.
- LEVEL 9: max angle starts to reduce when the truck speed is 100% of the maximum speed (No max angle reduction).

Each step has a weight of 11%.

### **Stepper Motor version:**

Level 0 to 9. This setting performs the Dynamic Numbness compensation: it consists of a reduction in the steer sensitivity when the truck is driving at high speed. To get this goal, it is necessary to attenuate the scaling factor between the speed of the steering wheel and the speed of the steering motor. AUX FUNCTION #2 does that but only when the steering wheel is **slow** turning. This attenuation must be proportional to the drive speed. At full drive speed the attenuation of the scaling factor is maximum.

AUX FUNCTION #2 to Level 0 means no attenuation of the scaling factor with the truck speed.

AUX FUNCTION #2 to Level 9 means maximum attenuation of the scaling factor with the truck speed.

Obviously, to perform the Dynamic Numbness compensation, it is necessary to know the drive speed and so the eps-ac0 must be CAN Bus connected.

## 6) KP

Level 0 to 9. It is used to set the proportional contribution to a PID algorithm for RTC and AUTC functions. The proportional contribution is applied to the difference between the commanded position and the real position (steered wheel angle). The accuracy of the pursuing between commanded and real position increases if KP increases. It is used in closed loop applications.

## 7) POS. ACCURACY

Level 0 to 9. It is used to set the proportional contribution to a PID algorithm for RTC and AUTC functions. The proportional contribution is applied to the difference between the commanded position and the real position (steered wheel angle). The accuracy of the pursuing between commanded and real position increases if POS. ACCURACY increases. POS. ACCURACY is used only for closed loop applications. KP and POS. ACCURACY are a coarse and a fine contribution to the same setting.

## 8) DYNAM NUMB ANG

Level 0 to 9. This parameter handles the Dynamic Numbness vs. the Steering Error for RTC and AUTC functions. This functions applies a linear

correspondence between the steering motor speed and the angle error between the actual commanded position and the latest steady state position of the steered wheel: when this angle error is wider than the angle specified with this setting, there will be no clamp on the steering motor speed (full speed steering motor is SET SAT FREQ plus OVERSAT FREQ); when this angle error is smaller than 40% of the angle specified with this setting, the maximum Numbness will be applied. This parameter sets the angle, between the commanded position and the latest steady state position, at which the steering motor speed gets its maximum value (SET SAT FREQ plus OVERSAT FREQ).

- LEVEL 0: No Numbness if the angle between tiller and latest steady state is higher than 5°.
- LEVEL 1: No Numbness if the angle between tiller and latest steady state is higher than 11°.
- LEVEL 2: No Numbness if the angle between tiller and latest steady state is higher than 17°.
- LEVEL 9: No Numbness if the angle between tiller and latest steady state is higher than 60°.

Each step has a weight of 6 degrees.

## 9) DYNAM NUMB SPEED

Level 0 to 9. This parameter handles the Dynamic Numbness vs. the Steering Error for RTC and AUTC functions. This functions applies a linear correspondence between the steering motor speed and the angle error between the actual commanded position and the latest steady state position of the steered wheel. This parameter sets the percentage of the full steering motor speed is applied when in the full Dynamic Numbness. The full steering motor speed is the sum of the SET SAT FREQ and OVERSAT FREQ settings. When the angle between the actual commanded position and the latest steady state position is less than 40% of the DINAM NUMB ANG setting, the Full Dynamic Numbness vs. the Steering Error is applied and the steering speed is clamped to the DYNAM NUMB SPEED percentage below.

- LEVEL 0: At full Dynamic Numbness, the steering motor frequency is clamped to 40% (maximum Numbness).
- LEVEL 1: At full Dynamic Numbness, the steering motor frequency is clamped to 46%.
- LEVEL 2: At full Dynamic Numbness, the steering motor frequency is clamped to 53%.
- LEVEL 9: At full Dynamic Numbness, the steering motor frequency is clamped to 100% (no Numbness).

Each step more has a weight of 6.6 %.

## 10) COMPENSATION

Level 0 to 2. This parameter applies a compensation for the drops in the motor connections to have a real Emf/f control law.

- LEVEL 0: No compensation.
- LEVEL 1: Compensate the drop on power mosfets and cables.
- LEVEL 2: Compensate the drop on power mosfet, cables and motor resistance.

COMPENSATION to LEVEL 2 is strongly suggested (the correct setting of the motor resistance is required when COMPENSATION is set to LEVEL 2-see 13.1).

## 11) AUXILIARY TIME

This parameter defines the time, after the steer handle is released and the travel demand deactivated, for which the stand still torque is applied.

- LEVEL 0: No stand still torque.
- LEVEL 1: Brief application of the stand still torque (about 6 secs).
- LEVEL 9: Long application of the stand still torque (about 90 secs).

Intermediate levels are for proportionally increasing auxiliary time. The stand still torque reduces with a ramp from the ANTIROLLBACK value down to zero with a delay specified with this setting.

## 12) ANTIROLLBACK

This parameter adjusts the standstill torque after the steer handle is released and the travel demand deactivated. It is in percentage of the maximum current. Injecting a continuous current in the motor generates the stand still torque. It is useful (together with the CREEP SPEED parameter, see 12.4.4.3) to neutralize the recall torque generated by the elastic tyre on the steered wheel.

## 13) 1ST ANGLE COARSE

Depending on the configuration, this parameter has different meaning.

### ***RTC version with feedback pot:***

This parameter regulates in coarse steps the maximum steered wheel angle in the direction where FEEDBACK ENC is higher than 2.5 V. It is a scaling factor between the SET POINT POT reading and the FEEDBACK ENC reading. By increasing this parameter, the maximum steered wheel angle increases too. The maximum angle in RTC should be regulated in feedforward way by properly adjusting the angle settings.

### ***Stepper Motor version with toggle switches:***

This parameter regulates in coarse steps the maximum steered wheel angle in the direction where FEEDBACK ENC is higher than 2.5 V. It limits the angle measured with the reading WHEEL ANGLE in the following range:

- LEVEL 0: Angle is limited to a WHEEL ANGLE is +80 degrees.
- LEVEL 1: Angle is limited to a WHEEL ANGLE is +84 degrees.
- LEVEL 9: Angle is limited to a WHEEL ANGLE is +118 degrees.

Each step has a weight of 3.8 degrees.

When 1ST ANGLE COARSE and 2ND ANGLE COARSE are both to Level 9, the angle limitation is inhibited.

## 14) 1ST ANGLE FINE

(RTC version only). This parameter regulates in fine steps the maximum steered wheel angle in the direction where FEEDBACK ENC is higher than 2.5 V. It is used in closed loop application only (RTC) and it is a scaling factor between the SET POINT POT reading and the FEEDBACK ENC reading.

By increasing this parameter, the maximum steered wheel angle increases too.

## 15) 2ND ANGLE COARSE

Depending on the configuration, this parameter has different meaning.

### ***RTC version with feedback pot:***

This parameter regulates in coarse steps the maximum steered wheel angle in the direction where FEEDBACK ENC is lower than 2.5 V. It is a scaling factor between the SET POINT POT reading and the FEEDBACK ENC reading.

By increasing this parameter, the maximum steered wheel angle increases too. The maximum angle in RTC should be regulated in feedforward way by properly adjusting the angle settings.

**Stepper Motor version with toggle switches:**

This parameter regulates in coarse steps the maximum steered wheel angle in the direction where FEEDBACK ENC is lower than 2.5 V. It limits the angle measured with the reading WHEEL ANGLE in the following range:

- LEVEL 0: Angle is limited to a WHEEL ANGLE is -80 degrees.
- LEVEL 1: Angle is limited to a WHEEL ANGLE is -84 degrees.
- LEVEL 9: Angle is limited to a WHEEL ANGLE is -118 degrees.

Each step has a weight of 3.8 degrees.

When 1ST ANGLE COARSE and 2ND ANGLE COARSE are both to Level 9, the angle limitation is inhibited.

**16) 2ND ANGLE FINE**

(RTC version only). This parameter regulates in fine steps the maximum steered wheel angle in the direction where FEEDBACK ENC is lower than 2.5 V. It is used in closed loop application only (RTC) and it is a scaling factor between the SET POINT POT reading and the FEEDBACK ENC reading.

By increasing this parameter, the maximum steered wheel angle increases too.

**17) NUMBNESS**

(RTC version only). This parameter reduces the steering sensitivity close to the straight-ahead direction.

- LEVEL 0: No reduction in the steer sensitivity with the steering angle.
- LEVEL 9: Steering 4.5 less sensitive in the straight ahead direction.

Intermediate reductions of sensitivity are applied for intermediate settings. The steering sensitivity increases in a proportional relationship with the increased steering wheel angle. To be more precise, by increasing the NUMBNESS setting, no sensitivity modification is applied when the steering wheel is close to be straight, but higher sensitivity is applied when the steering wheel is angled. As consequence, when changing the NUMBNESS value, it is necessary to re-adjust the maximum angle limitations with the settings 1ST ANGLE COARSE (and FINE) and 2ND ANGLE COARSE (and FINE).

**18) LAG FB REGULAT**

Level 0 to 9. It is used to set the integral (lag) contribution to a PID algorithm for RTC and AUTC functions. The integral contribution is applied to the FEEDBACK ENC value only. It works like a low pass filter to get smooth the pursuing next to the commanded position. The derivative (lead) contribution generates dither that is possible to reduce by increasing this adjustment. Obviously lag and lead regulations influence the stability of the closed loop and so different setting must be empirically tried to avoid oscillations.

- LEVEL 0: lowest lag contribution (high cut off frequency low pass filter).
- LEVEL 9: highest lag contribution (low cut off frequency low pass filter).

**19) LEAD FB REGULAT**

Level 0 to 9. It is used to set the derivative (lead) contribution to a PID algorithm for RTC and AUTC functions. The derivative contribution is applied to the FEEDBACK ENC value only. High LEAD FB REGULAT value brakes the steering motor in advance respect to the commanded position so avoiding the

overshooting of the commanded position. On the other side generates damping and dither, close to the commanded position. Obviously lag and lead regulations influence the stability of the closed loop and so different setting must be empirically tried to avoid oscillations.

- LEVEL 0: lowest lead contribution (overshooting is favourite).
- LEVEL 9: highest lead contribution (damping is favourite).

### 12.4.5 Zapi menu “HARDWARE SETTINGS” functions list

To enter this Zapi hidden menu a special procedure is required. Ask this procedure directly to a Zapi technician.

**1) MAXIMUM CURRENT**

MAXIMUM CURENT sets the limit for the current in the controller.

**2) CAN BUS**

ABSENT or PRESENT. This setting specifies whether the eps-ac0 is CAN Bus connected or not. When CAN BUS is ABSENT, the CAN BUS KO alarm is inhibited together with any starting sequence used to synchronize via CAN Bus the eps-ac0 with the other controllers.

**3) SET HI RESOL AD**

When it is set to Level 1, enables an analog to digital conversion with high resolution applied to the command pot CPOC1. Level 0 means the high resolution AD conversion is inhibited. Level 2 is not used.

## 12.4.6 Zapi menu “SPECIAL ADJUSTMENT” functions list

To enter this Zapi hidden menu a special procedure is required. Ask this procedure directly to a Zapi technician.

### 1) HIGH ADDRESS

Zapi reserved.

### 2) SET TEMPERATURE

Factory adjusted.

### 3) MAX SP SLOPE

(RTC version only). This setting is used to adjust the slope threshold for the STEER SENSOR KO alarm (see 14.1.3.6).

This alarm occurs when the slope of one of the set point potentiometers (CPOC1 or CPOC2) is detected larger than the MAX admitted slope. The MAX admitted slope is specified with this setting:

- LEVEL 0: the max admitted slope is 61 corresponding to 0.3 V in 16 msec. (i.e. STEER SENSOR KO alarm occurs when either CPOC1 or CPOC2 changes more than  $\pm 0.3$  V in 16 msec. This means that the SLOPE PEAK reading in the tester menu assumes larger than  $\pm 61$  value. See 12.4.7.23).
- LEVEL 1: the max admitted slope is 79 corresponding to 0.39 V in 16 msec.
- LEVEL 2: the max admitted slope is 97 corresponding to 0.47 V in 16 msec.
- LEVEL 3: the max admitted slope is 115 corresponding to 0.56 V in 16 msec.
- LEVEL 4: the max admitted slope is 133 corresponding to 0.65 V in 16 msec.
- LEVEL 5: the max admitted slope is 151 corresponding to 0.74 V in 16 msec.
- LEVEL 6: the max admitted slope is 169 corresponding to 0.83 V in 16 msec.
- LEVEL 7: the max admitted slope is 187 corresponding to 0.91 V in 16 msec.
- LEVEL 8: the max admitted slope is 205 corresponding to 1.00 V in 16 msec.
- LEVEL 9: the max admitted slope is 410 corresponding to 2.00 V in 16 msec.

Default value is LEVEL 9.

Pay attention the LEVEL 9 gets the alarm strongly insensitive and it is the right setting only when the twin pot redundancy is adopted for the set point potentiometer; when just one single set point potentiometer is adopted, we advice against using LEVEL 9.

### 4) DEBUG OUTPUT

This adjustment is used to temporary change the configuration or inhibit some diagnosis to aid the troubleshooting. Take care to set DEBUG OUTPUT to Level 15 after finishing the troubleshooting.

- LEVEL 0: Self-acquisition of the stepper motor offsets (see 12.4.2.11-12) in open loop application. It switches automatically to the default Level 15 after the self-acquisition.

- LEVEL 1-9 Zapi reserved.
- LEVEL 10: Enables the NO LOAD CURRENT test (see 12.4.2.10). Roll from level 10 to level 15 and save the new setting to exit this testing condition.
- LEVEL 11: Disables the alarms FB SENS LOCKED, MOTOR LOCKED and POSITION ERROR (the latest only for FB ENC & Toggle Switches configuration) till a new DEBUG OUTPUT hand setting.
- LEVEL 12: The SET POINT POT of the Tester menu is connected at the high resolution AD input (it is in the range 0 to 5Vdc when the command potentiometer (CPOC1) is close to ZERO SP POT).
- LEVEL 13: Reading SET POINT POT in the tester menu is connected to the 2nd wiper of the twin (command) pot (CPOC2 on CNA#8).
- LEVEL 14: Disables the alarms FB POT LOCKED, MOTOR LOCKED and POSITION ERROR (the latest only for FB ENC & TOGGLE SWs configuration). It switches automatically to the default Level 15 recycling the key.
- LEVEL 15: Default value (no special functions activated).

## 12.4.7 Main menu “TESTER” functions list

The TESTER functions are real time feedback measurements of the state of the controller. It is possible to know the state (active disactive) of the digital I/Os, the voltage value of the analog inputs and the state of the main variables used in the motor. Enter the headline in the hand-set display and roll for the TESTER item.

**1) STEPPER MOTOR**

Voltage value with 2 decimal digit. Measurement of the stepper motor speed with sign in the range 0 to  $\pm 5$  Vdc.

**2) SET POINT POT**

Voltage value with 2 decimal digit. Measurement of the potentiometer connected to CNA#9 (CPOC1). Switch DEBUG OUTPUT to level 13 to get CNA#8 (CPOC2) on this reading (see 12.4.6.4).

**3) FEEDBACK POT**

(feedback pot version only). Voltage value with 2 decimal digits. Measurement of the feedback potentiometer connected to CNB#6 (CPOT).

**4) FEEDBACK SECTOR**

(toggle switches version only). Voltage value with 2 decimal digits. It supplies real time the information of the sector (quadrant) detected through the toggle switches. It assume the following value:

3.13 V in the sector from 0 to +90 degrees.

4.39 V in the sector from +90 to +180 degrees.

0.62 V in the sector from -180 to -90 degrees.

1.88 V in the sector from -90 to 0 degrees.

**5) FEEDBACK ENC**

Voltage value with 2 decimal digit. Measurement (scaled in the range 0 to 5 Vdc) of the position of the feedback encoder connected to CNB#7 and CNB#8.

**6) TEMPERATURE**

Degrees. Temperature of the controller base plate.

**7) MOTOR TEMPERATURE**

Degrees. Temperature of the motor windings measured with the thermal sensor inside the motor and connected to CNB#3.

**8) FREQUENCY**

Hertz value with 2 decimal digit. This is the frequency applied to the steering motor.

**9) SAT. FREQ HZ**

Hertz value with 2 decimal digit. This is a real time magnetic flux measurement: Vbattery/ SAT. FREQ HZ provides real time the linked flux in the motor. The flux in the motor is modulated from 75% to 100% of the maximum flux.

The maximum flux is Vbattery/SET SAT FREQ.

The minimum flux is Vbattery/(1.33\*SET SAT FREQ). When the motor is loaded, SAT. FREQ HZ is equal to SET SAT FREQ; when the motor is

lightened the flux reduces and SAT. FREQ HZ increases up to 1.33\*SET SAT FREQ.

**10) MOTOR VOLTAGE**

It is a percentage. 100% means the sine waves in the motor have the maximum PWM amplitude.

**11) MOTOR CURRENT**

Ampere value. Root Mean Square value of the line current in the motor.

**12) ENC SPEED**

Hertz value with 2 decimal digit. This is the speed of the motor measured with the encoder on the motor shaft.

**13) ENDSTROKE CW**

Provides real time the active state (ON) or not of the CW toggle switch (connected to CNA#3). It is On when CNA#3 is low (see 7.5).

**14) ENDSTROKE ACW**

Provides real time the active state (ON) or not of the CCW toggle switch (connected to CNA#2). It is On when CNA#2 is low (see 7.5).

**15) CW LIMIT LEVEL**

When the maximum angle limitation via feedback sensors is enabled (option LIMIT DEVICE to ON when FEEDBACK DEVICE is OPTION #1,2,3; 1<sup>ST</sup> ANGLE COARSE and 2<sup>ND</sup> ANGLE COARSE less than level 9 when FEEDBACK DEVICE is OPTION #4) and the FEEDBACK ENC overtakes the superior limit for the steered wheel angle limitation, the steered wheel angle will be limited and CW LIMIT LEVEL turns ON (active).

**16) ACW LIMIT LEVEL**

When the maximum angle limitation via feedback sensors is enabled (option LIMIT DEVICE to ON when FEEDBACK DEVICE is OPTION #1,2,3; 1<sup>ST</sup> ANGLE COARSE and 2<sup>ND</sup> ANGLE COARSE less than level 9 when FEEDBACK DEVICE is OPTION #4) and the FEEDBACK ENC is lower than the inferior limit for the steered wheel angle limitation, the steered wheel angle will be limited and ACW LIMIT LEVEL turns ON (active).

**17) AUTO IN PROGRESS**

Provides real time the information the eps-ac0 follows the manual command (AUTO IN PROGRESS is OFF) or is executing an automatic centering (AUTO IN PROGRESS is ON).

**18) MM ALARM SWITCH**

It is On when the safety contact belonging to the main uC is closed.

**19) SM ALARM SWITCH**

It is On when the safety contact belonging to the slave uC (supervisor) is closed.

**20) TRUCK MOVING**

It provides the state of the travel demand for driving the truck. This information is obtained either with the travel demands directly connected to CNA#1 or via CAN Bus (depending by the state of the CAN BUS setting see 12.4.5.2).

**21) HIGH RESOL AD**

It turns ON when the set point potentiometer is processed with a high resolution AD.

## 22) WHEEL ANGLE

Angle measurement degrees. For the configuration with toggle switches only, it is the steered wheel angle in the range  $0 \pm 180$  degrees. WHEEL ANGLE is zero in the position where an edge is detected in the straight ahead toggle switch.

## 23) SLOPE PEAK

This reading is just for debugging the maximum slope of the potentiometers connected to the eps-ac0. Especially when a reduced sensor equipment is chosen (just a single command potentiometer or just a single feedback potentiometer without encoder), a concern regarding the safety raises: if a single potentiometer fails a sudden movement of the steered wheel may occur with danger. To avoid this problem it is necessary to detect any failure in a single potentiometer. This is hard to do because the failure mode can be quite different. Anyway, the best countermeasure we can take, is to seek for the wiper voltage changes faster than its physical limit. In fact, for the limited speed of the steering motor (or of the steering wheel), the slope in the wiper voltage must be limited under a certain threshold. When this slope threshold is overtook, the potentiometer may be assumed broken. So, it is useful to measure the maximum slope occurring in your application when right working, in order a right slope threshold can be chosen to avoid an alarm occurs when the potentiometer is not failed (see 12.4.6.3).

The SLOPE PEAK reading in the tester menu is a real time measurement of the slope peak of the potentiometers. In particular:

When the special adjustments DEBUG OUTPUT is other than Level 12 or 13, SLOPE PEAK supplies the slope peak of the CPOC1 set point potentiometer (CNA#9).

When the special adjustments DEBUG OUTPUT is Level 13, SLOPE PEAK supplies the slope peak of the CPOT feedback potentiometer (CNB#6).

When the special adjustments DEBUG OUTPUT is Level 12, SLOPE PEAK supplies the slope peak of the CPOC2 set point potentiometer (CNA#8).

The SLOPE PEAK measurement is the difference between two AD conversions of the selected potentiometer picked up with 16 msec long interval. The SLOPE PEAK reading can be converted in a Voltage change ( $\Delta V$  in volts) of the wiper voltage in an interval 16 msec long, with the formula:

$$\Delta V = \text{SLOPE PEAK} * 5 / 1024 = \text{Voltage change in Volts in 16 msec}$$

(e.g. When SLOPE PEAK is 61 it means the selected potentiometer, in the worst case, changes  $61 * 5 / 1024 = 0.3$  V in 16 msec.).

Obviously the SLOPE PEAK reading must be compared with the threshold for the STEER SENSOR KO and JERKING FB POT alarms (see 14.1.3.6-7). The STEER SENSOR KO alarm may be adjusted (see MAX SP SLOPE 12.4.6.3); the JERKING FB POT occurs when the CPOT slope, overtakes a constant threshold is  $\pm 0.3$  V in 16 msec (i.e. SLOPE PEAK =  $\pm 61$ ).

## 24) READ FBPT AT SW1

This reading is used only when the FEEDBACK DEVICE is OPTION #3 (FBENC, FBPOT, SW1). It gives the FB POT value at the initial matching with the falling edge on the straight ahead switch (SW1). This reading is expected to reply the SET FBPOT AT SW1 value (see 12.4.2.18 in the adjustments menu). When a displacement exists between these two readings, a POSITION ERROR alarm may occur (see 14.1.3.5).

## 25) TRUCK SPEED

Percentage value. It represents the truck speed represented in percentage of

the full drive speed. It is used for the dynamic numbness (i.e. the steering sensitivity reduces when the truck speed increases).

**26) ENC COUNT AT 360**

(only when FEEDBACK DEVICE is OPTION #4). This reading shows the encoder counting between two falling edges on the straight ahead switch. It must be meant as the encoder counting corresponding to a steered wheel revolution. It is scaled in the range 0 to  $\pm 5$  V with the meaning that 5 V corresponds to an encoder counting of  $2^{15}$  events. The ENC COUNT AT 360 absolute value can be recorded on the adjustment SET ENC AT 360.

# 13 OTHER FUNCTIONS

Here is a list of special functions hand set assisted, that are not documented yet.

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## 13.1 Acquiring the Motor resistance

When it is possible, the steering motor is controlled sensorless. To get the best performance in terms of the max torque generated, it is necessary to compensate for the drop in the motor resistance. So the correct value of the motor resistance must be known.

Eps-ac0 provides a self-acquisition procedure to acquire the motor resistance. It is just enough to connect the eps-ac0 to the battery, to the motor and to the wiring in order no alarm occurs. Then:

- 1) Enter the ADJUSTMENTS menu searching for ADJUSTMENT #01 setting.
- 2) Turn ADJUSTMENT #01 to Level 1. (A DATA ACQUISITION alarm occurs and a half I<sub>max</sub> DC current is automatically injected in the motor).
- 3) Wait about 2 secs.
- 4) Roll ADJUSTMENT #01 back to Level 0.
- 5) Save the new setting.

With this procedure the resistance between two motor terminals is automatically measured and recorded (in milliohms) on the ADJUSTMENT #02 (see 12.4.2.3). It is also possible to adjust the motor resistance value without self-acquisition by rolling the ADJUSTMENT #02.

The acquisition of the motor resistance should be performed to find the correct value when developing a new truck prototype; the correct value will be the default setting for the mass production of that truck.

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## 13.2 Alignment at the rest position

In the open loop applications (i.e. when the stepper motor is used in the steering wheel or the steer command is a speed information coming via CAN bus) an alignment at the rest position is automatically performed when the steered wheel has a drift with a released steering wheel. This alignment at the rest position is handled closed loop and so a feedback sensor is required. So this function is performed only either with SYSTEM CONFIG to level 0 or with SYSTEM CONFIG to level 4. When the feedback sensor uses a feedback potentiometer, the alignment at rest position is performed for both cases (SYSTEM CONFIG to level 0 and 4) provided that option LIMIT DEVICE is ON. When the feedback sensor uses toggle switches, the alignment at the rest position is performed only when SYSTEM CONFIG is level 0.

---

## 13.3 Straight ahead steering numbness

It is possible to reduce the steering sensitivity while the steered wheel is close to be straight ahead by using the NUMBNESS setting in the PARAMETERS CHANGE menu. Increasing the NUMBNESS parameter gets the steering less responsive when the truck is driving next to the straight ahead direction (i.e. a certain increment of the steering wheel angle gets a smaller increment of the steered wheel angle when the truck is driving straight ahead than when it is angled).

Higher NUMBNESS setting results in higher numbness of the steering at low steered wheel angle. NUMBNESS to Level 0 results in a linear relationship between the command and the steered wheel angle (no sensitivity reduction in straight ahead).

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## 13.4 Special Debugging and Troubleshooting system

Eps-ac0 provides a special adjustment (DEBUG OUTPUT) to facilitate the troubleshooting. Some alarms may be due to many different causes that are difficult to catch. In particular, the alarms in which the steered wheel does not pursuit the commanded positions (FB POT LOCKED, FB SENSOR LOCK, MOTOR LOCKED, POSITION ERROR) may be due to a mechanical fault or to a failed sensor or to a problem in the motor. It is difficult to find the root for the problem in the short time before the alarm occurs. For this reason the eps-ac0 provides a method to temporary inhibit these alarms. It is just enough to set the special adjustment DEBUG OUTPUT to Level 11. Then the steering system works without these alarms and the service can take longer time to analyze the system and to catch the fault. Together with this possibility DEBUG OUTPUT provides many other special functions (that are described in paragraph 12.4.6.4). For example it is possible to use the hand set to read the voltage from the second twin pot wiper (CPOC2 on CNA#8) on the reading SET POINT POT of the hand set. It is just enough to turn DEBUG OUTPUT to level 13.



***Don't forget to turn DEBUG OUTPUT to Level 15 after finished the test.***

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# 14 EPS-AC0 ALARMS LIST

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

- 1) The alarm code
- 2) The times that each alarm occurs consecutively
- 3) The Hour Meter value when the latest event of every alarm occurred
- 4) The inverter temperature when the latest event of every alarm occurred.

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

The CAN Bus code is the corresponding number with which the alarm is signalled on the CAN Bus (ID 0x298h).

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## 14.1 Main menu “ALARMS” list

To Enter the MAIN MENU push the Enter button at the Home Page of the hand set display and Roll for the ALARMS item. Here is the ALARMS list:

### 14.1.1 One Blink Alarms

#### 1) MICRO SLAVE KO

**CAN Bus Code = 246**

- Cause: In stepper motor application, this alarm occurs if the main uC is detecting a direction of the stepper motor not matched with the one that the slave uC is detecting.  
In closed loop application, this alarm occurs if the main uC is detecting a direction of the steering error not matched with the one that the slave uC is detecting.  
Furthermore, this alarm occurs also if the main uC is detecting no steering limitation meanwhile the slave uC is detecting e steering limitation.
- Remedy: It is necessary to replace the controller.

#### 2) MICRO SLAVE #4

**CAN Bus Code = 221**

- Cause: It occurs in one of the following conditions:  
(Open loop application only) If the slave uC detects the stator voltage phasor rotates in the opposite direction respect to the sign of the stepper motor speed, this alarm occurs.  
(Closed loop application only) If the slave uC detects the stator voltage phasor rotates in the opposite direction respect to the commanded position, this alarm occurs.
- Remedy: It is necessary to replace the controller.

#### 3) MICRO SLAVE

**CAN Bus Code = 250**

- Cause: It occurs when the information on the status bus between the main uC and the slave uC is frozen to the 0xFF value (the slave uC does not update the status bus configuration).
- Remedy: It is necessary to replace the controller.

#### 4) MICRO SLAVE #8

##### **CAN Bus Code = 212**

- Cause: It occurs when the encoder counting of the main uC is not matched with the encoder counting of the slave uC.
- Remedy: It is necessary to replace the controller.

#### 5) INPUT ERROR #1

##### **CAN Bus Code = 99**

- Cause: It occurs when the voltage on CNA#4 (NK1: Lower Potential Terminal of the Safety Contacts (see 7.6) is higher than 12 V before to turn the safety contacts closed.
- Remedy: When the safety contacts are open, the voltage on CNA#4 is expected to be close to 0 Vdc and this is independent from whether the safety contacts are connected to a plus battery or to a minus battery (see 7.6). In the first case (safety contacts connected to a plus battery), when the safety contacts are open, CNA#4 is connected to a minus battery through a load. Only a harness mistake may connect NK1 to a higher than 12 V voltage.

#### 6) SERIAL ERR #1

##### **CAN Bus Code = 6**

- Cause: Main uC and Slave uC communicate via a local serial interface. This alarm occurs when the slave uC does not receive the communication from the main uC through this serial interface.
- Remedy: It is necessary to replace the controller.

#### 7) SLAVE COM. ERROR

##### **CAN Bus Code = 227**

- Cause: Main uC and Slave uC communicate via a local serial interface. This alarm occurs when the main uC does not receive the communication from the slave uC through this serial interface.
- Remedy: It is necessary to replace the controller.

#### 8) NO SYNC

##### **CAN Bus Code = 226**

- Cause: Every 16msec, inside the code cycle, the main uC rises and then lowers an input for the slave uC (SYNC). When the slave uC detects no edge for more than 100 msec on this input, this alarm occurs. This is just a watch dog function: when the main uC does not execute the code cycle it does not update the SYNC signal and the slave uC cuts off the steer and traction.
- Remedy: It is necessary to replace the controller.

#### 9) KM CLOSED

##### **CAN Bus Code = 253**

- Cause: This alarm occurs at key on if the slave uC detects the safety contact, of the main uC, closed prior to be commanded.
- Remedy: This alarm occurs if the connection CNA#5 (K1) is around a voltage of 12 Vdc when switching on the key. In fact, when the safety contacts are open, K1 is expected being connected to a battery voltage (not 12 V). Search for a harness problem or replace the controller.

#### 10) KM OPEN

##### **CAN Bus Code = 251**

- Cause: This alarm occurs if the slave uC detects the safety contact, of the main uC, open when expected being closed.
- Remedy: It is necessary to replace the controller.

#### 11) KS CLOSED

##### **CAN Bus Code = 254**

- Cause: This alarm occurs if the main uC detects the safety contact, of the slave uC, closed prior to be commanded.
- Remedy: This alarm occurs if the connection CNA#4 (NK1) is around a voltage of 12 Vdc when switching on the key. In fact, when the safety contacts are open, NK1 is expected being connected to a minus battery voltage (not 12 V). Search for a harness problem or replace the controller.

#### 12) KS OPEN

##### **CAN Bus Code = 252**

- Cause: This alarm occurs if the main uC detects the safety contact, of the slave uC, open when expected being closed.
- Remedy: It is necessary to replace the controller.

#### 13) CLOCK PAL NOT OK

##### **CAN Bus Code = 218**

- Cause: The main uC sends an analog signal towards the slave uC to reset the slave uC on demand. When the slave uC detects this analog signal external to a window from 2.2 to 2.8 and not in the range to generate the reset on demand, the slave uC raises this alarm.
- Remedy: It is necessary to replace the controller.

### 14.1.2 Two Blinks Alarms

#### 1) HIGH CURRENT

##### **CAN Bus Code = 70**

- Cause: This alarm occurs if the circuit to limit via hardware the current in the motor is either always active at key-on or repeatedly active when the motor is turning.
- Remedy: Check the motor is suited to work with the eps-ac0 (not oversized). Otherwise it is necessary to replace the controller.

#### 2) POWER FAILURE #1

##### **CAN Bus Code = 73**

- Cause: This alarm occurs when the current in the phase W of the motor is zero and the motor is commanded for moving.
- Remedy: Check the power fuse is OK. Check the battery positive arrives to the controller. Check the continuity of the wire in the phase W of the motor. Otherwise it is necessary to replace the controller.

#### 3) POWER FAILURE #2

##### **CAN Bus Code = 72**

- Cause: This alarm occurs when the current in the phase U of the motor is zero and the motor is commanded for moving.
- Remedy: Check the power fuse is OK. Check the battery positive arrives to the controller. Check the continuity of the wire in the phase U of the motor. Otherwise it is necessary to replace the controller.

#### 4) POWER FAILURE #3

##### **CAN Bus Code = 71**

- Cause: This alarm occurs when the current in the phase V of the motor is zero and the motor is commanded for moving.
- Remedy: Check the power fuse is OK. Check the battery positive arrives to the controller. Check the continuity of the wire in the phase V of the motor. Otherwise it is necessary to replace the controller.

#### 5) LOGIC FAILURE #1

##### **CAN Bus Code = 19**

- Cause: This alarm occurs when the real voltage between phases W and U of the motor is different from the desired.
- Remedy: It is necessary to replace the controller.

#### 6) LOGIC FAILURE #2

##### **CAN Bus Code = 18**

- Cause: This alarm occurs when the real voltage between phases W and V of the motor is different from the desired.
- Remedy: It is necessary to replace the controller.

#### 7) MAIN CONT. OPEN

##### **CAN Bus Code = 48**

- Cause: This alarm occurs only when the setting CAN BUS is PRESENT. Then the eps-ac0 waits for a via CAN information that the traction controller has closed the main contactor. If this information lacks more than about 1.5 secs, this alarm occurs.
- Remedy: Find, on the traction controller, the reason for keeping the main contactor open.

#### 8) CAN BUS KO

##### **CAN Bus Code = 247**

- Cause: This alarm occurs only when the setting CAN BUS is PRESENT. Then the eps-ac0 must receive the event messages from the traction controller. If these messages lack more than about 1 sec, this alarm occurs.
- Remedy: Check the CAN Bus communication system and analyse the frames from the traction controller to the steer controllers.

#### 9) MOTOR LOCKED

##### **CAN Bus Code = 220**

- Cause: This alarm occurs if the current in the steering motor stays close to the maximum current longer than 1 sec.
- Remedy: Search for a mechanical problem locking the motor. To make easier the fault catching, set DEBUG OUTPUT to level 11 (see 12.4.6.4).

### 14.1.3 Three Blinks Alarms

#### 1) D LINE SENSOR KO

##### **CAN Bus Code = 243**

- Cause: This alarm occurs when the mean voltage on the Direct line of the stepper motor (connection CNA#9) is not null: the voltage on every stepper motor line is a sine wave with null mean voltage.
- Remedy: Check the continuity of the stepper motor connections. In particular the resistance between CNA#9 and the minus battery (with the

stepper motor at rest) is expected being very low (close to 30 ohms).

## 2) Q LINE SENSOR KO

### **CAN Bus Code = 242**

- Cause: This alarm occurs when the mean voltage on the Quadrature line of the stepper motor (connection CNA#8) is not null: the voltage on every stepper motor line is a sine wave with null mean voltage.
- Remedy: Check the continuity of the stepper motor connections. In particular the resistance between CNA#8 and the minus battery (with the stepper motor at rest) is expected being very low (close to 30 ohms).

## 3) S.P OUT OF RANGE

### **CAN Bus Code =248**

- Cause: This alarm occurs for a fault on the command potentiometer (CPOC1 on CNA#9, CPOC2 on CNA#8).  
When a single command pot is chosen, the alarm occurs if its wiper (CPOC1) exits the range from 0.8 Vdc to 4.2 Vdc.  
When the twin pot is chosen, the alarm occurs if the sum of the two wiper voltages (CPOC1+CPOC2) exits the range from 4.5 Vdc to 5.5 Vdc.
- Remedy: Check the connections of the potentiometer. This alarm occurs when one connection of the command potentiometer is broken.

## 4) F.B OUT OF RANGE

### **CAN Bus Code =249**

- Cause: This alarm occurs for a fault on the feedback potentiometer (CPOT on CNB#6). This alarm occurs if CPOT exits the range from 0.3 Vdc to 4.7 Vdc.
- Remedy: Check the connections of the feedback potentiometer. This alarm occurs when one connection of the feedback potentiometer is broken.

## 5) POSITION ERROR

### **CAN Bus Code =228**

- Cause: This alarm occurs for an error in the redundant test of the feedback sensors.
  - 1) When the feedback potentiometer is used together with the feedback encoder, the angle of the steered wheel is measured with both of them: FEEDBACK ENC and FEEDBACK POT in the tester menu are expected to be equal. When they are different more than 20 degrees this alarm occurs (SET MAX FB POT–SET MIN FB POT corresponds to 180 degrees).
  - 2) When the feedback encoder is used together with toggle switches, this alarm occurs if the sector (toggles switches configuration) and the encoder counting are not matched. The sector is provided via the FEEDBACK SECTOR reading in the tester menu; the encoder counting is provided via the WHEEL ANGLE reading in the tester menu. In particular (in case of two toggle switches):

<b>WHEEL ANGLE [degrees]</b>	<b>Admitted sector</b>	<b>Admitted FEEDBACK SECTOR</b>
-22 to +22	1 <sup>st</sup> or 4 <sup>th</sup>	3.13 V or 1.88 V
+23 to +67	1 <sup>st</sup>	3.13 V
+68 to +112	1 <sup>st</sup> or 2 <sup>nd</sup>	3.13 V or 4.39 V
+113 to +157	2 <sup>nd</sup>	4.39 V
+158 to -158	2 <sup>nd</sup> or 3 <sup>rd</sup>	4.39 V or 0.62 V
-157 to -113	3 <sup>rd</sup>	0.62 V
-112 to -68	3 <sup>rd</sup> or 4 <sup>th</sup>	0.62 V or 1.88 V
-67 to -23	4 <sup>th</sup>	1.88 V

- Remedy: Check the potentiometer connected to CNB#6 is right working. If toggle switches are connected to CNA#2 and CNA#3, verify they are right working and the setting AUX FUNCTION 11 (see 12.4.1.9) is correct. Verify also the sensor bearing in the motor (encoder) has not a slip (the sensor bearing has two rings: one is connected to the rotor shaft; the other is connected to the motor frame. Check these two rings are strictly connected to their structure without slip.

#### 6) STEER SENSOR KO

##### **CAN Bus Code =84**

- Cause: This alarm occurs if the command potentiometer (CPOC1 on CNA#9 or CPOC2 on CNA#8) changes with a jerk larger than MAX SP SLOPE (see 12.4.6.3). This alarm is used to catch a discontinuity in the voltages of the command potentiometer.
- Remedy: Change the twin pot.

#### 7) JERKING FB POT

##### **CAN Bus Code =223**

- Cause: This alarm occurs if the feedback potentiometer (CPOT on CNB#6) changes with a jerk larger than 0.3 V in 16 msec. This alarm is used to catch a discontinuity in the voltages of the feedback potentiometer.
- Remedy: Change the feedback potentiometer.

#### 8) FB POT LOCKED or FB SENS LOCKED

##### **CAN Bus Code =222**

- Cause: In application with a feedback potentiometer, this alarm occurs if the feedback potentiometer (CPOT on CNB#6) does not change (or changes in the opposite direction) its value even if commanded to change.  
In application with toggle switches with ENCODER CONTROL to off, this alarm occurs if the feedback encoder counting does not change its value even if commanded to change.
- Remedy: In application with the feedback potentiometer, verify the feedback potentiometer is not mechanically loosened. Check there is not a mechanical block of the steered wheel.  
Be sure the wiper has not reached its own electrical limit because of too much angle of the steered wheel.  
Besides, this alarm may occur at the installation when the motor rotates in the wrong direction turning away from the wished

position.

In application with toggle switches, verify the encoder is not mechanically loosened. Check there is not a mechanical block of the steered wheel.

To make easier the fault catching, set DEBUG OUTPUT to level 11 (see 12.4.6.4).

#### 9) STEPPER MOTOR MISM

##### **CAN Bus Code =219**

- Cause: This alarm occurs if the frequency and the amplitude of the voltages from the stepper motor lines are mismatched in between (i.e. the voltage from the D and Q line of the stepper motor have high amplitude but with very low frequency). In normal condition when the amplitude of the stepper motor lines increases, the frequency of the stepper motor lines must increase too.
- Remedy: It is necessary to replace the controller.

#### 10) ENCODER ERROR

##### **CAN Bus Code =241**

- Cause: It occurs when ENCODER CONTROL is set ON and the real frequency does not pursuit the commanded frequency
- Remedy: This condition is several times due to either, a mismatching between the Encoder resolution used in the SW and the real encoder resolution, or a wrong connection between the two encoder channels. In this latest case exchange in between the two encoder channels.

#### 11) BAD ENCODER SIGN

##### **CAN Bus Code =83**

- Cause: It occurs in applications with toggle switches when the applied frequency (FREQUENCY) and the motor speed (ENC SPEED) have opposite sign.
- Remedy: Swap in between the two encoder channels (CNB#7 with CNB#8).

### 14.1.4 Four Blinks Alarms

#### 1) EEPROM KO

##### **CAN Bus Code = 13**

- Cause: It occurs if a test to write and read one location in EEPROM fails. The SW expects to read the written value. It occurs also when the hour counter gives different values between the three redundant locations in which it is recorded. It occurs also when the busy bit of the EEPROM does not rise within 12 msec.
- Remedy: It is necessary to replace the controller.

#### 2) GAIN EEPROM KO

##### **CAN Bus Code = 244**

- Cause: The parameters to compensate for the gain of the current amplifiers (ADJUSTMENT #03 and ADJUSTMENT #04) are recorded in a not volatile memory (eeprom) with a redundant handling. In fact every adjustment is recorded in three eeprom locations. If the values in these three locations are different in between this alarm occurs.
- Remedy: It is necessary to send the controller to Zapi to execute the maximum current regulation.

### 3) CURRENT GAIN

#### **CAN Bus Code = 225**

- Cause: This alarm occurs when the parameters to compensate for the gain of the current amplifiers (ADJUSTMENT #03 and ADJUSTMENT #04) have the default values (i.e. the maximum current was not regulated).
- Remedy: It is necessary to send the controller to Zapi to perform the maximum current regulation.

## 14.1.5 Five Blinks Alarms

### 1) HIGH TEMPERATURE

#### **CAN Bus Code = 61**

- Cause: This alarm occurs if the temperature of the controller base plate overtakes 75 degrees.
- Remedy: Improve the cooling of the controller; otherwise it is necessary to replace the controller.

### 2) MOTOR TEMPERAT.

#### **CAN Bus Code = 65**

- Cause: This alarm occurs only when DIAG MOTOR TEMP is on and the thermal sensor inside the motor measures a temperature higher than 150 degrees. It occurs also when trying to acquire the motor resistance with a temperature in the motor higher than 150 degree (still with DIAG MOTOR TEMP to ON).
- Remedy: Check the thermal sensor in the motor is right working. If it is, improve the cooling of the motor.

## 14.1.6 Six Blinks Alarms

### 1) STBY I HIGH

#### **CAN Bus Code = 53**

- Cause: This alarm occurs two ways:
  - 1) In the initial rest state after key on, if the outputs of the current amplifiers are not comprised in the window 2.2 to 2.8 Vdc.
  - 2) After the initial diagnosis this alarm occurs when the outputs of the current amplifiers at rest have a drift larger than  $\pm 0.15$  V.
- Remedy: It is necessary to replace the controller.

### 2) VMN NOT OK

#### **CAN Bus Code = 32**

- Cause: This alarm occurs in the initial rest state after key on if the outputs of the motor voltage amplifiers are not in the window from 2.2 to 2.8 Vdc.
- Remedy: It is necessary to replace the controller.

### 3) LOGIC FAILURE #3

#### **CAN Bus Code = 17**

- Cause: This alarm occurs in the rest state if the output of the voltage amplifier of the phase Vu-Vw have a drift larger than  $\pm 0.25$  V.
- Remedy: It is necessary to replace the controller.

### 4) LOGIC FAILURE #4

#### **CAN Bus Code = 16**

- Cause: This alarm occurs in the rest state if the output of the voltage amplifier of the phase Vw-Vv have a drift larger than  $\pm 0.25$  V.
- Remedy: It is necessary to replace the controller.

### 14.1.7 Thirty-two Blinks Alarms

#### 1) DATA ACQUISITION

##### **MDI-PRC Code = 245**

- Cause: This alarm occurs when the acquiring the motor resistance or when adjusting the parameters to compensate for the gain of the current amplifiers (maximum current factory adjusted).
- Remedy: Recycle the key.

### 14.1.8 No Blink Alarms (Warning)

These alarms do not cut the truck off; they only reduce the truck speed. So they warn the operator of a particular state in the truck.

#### 1) STEER HAZARD

##### **CAN Bus Code = 85**

- Cause: This is just a warning to inform that the steering controller is limiting the angle in the steering direction. No speed reduction occurs on the traction.

#### 2) WAITING DATA

##### **CAN Bus Code = 237**

- Cause: This warning occurs only if CAN BUS is PRESENT. At key-on the eps-ac0 asks to the traction controller to send a list of parameters via CAN Bus. From the request until the parameters are correctly relieved, this warning occurs. The steer is not activated yet, and the safety relays remain open when this warning is present.

#### 3) WAITING FOR TRAC

##### **CAN Bus Code = 239**

- Cause: At key-on the eps-ac0 needs an assent from the traction controller to close the safety contacts and to turn onto operational mode. Until this assent is not relieved, this warning occurs. The steer is not activated yet and the safety relays remain open when this warning is present.

#### 4) EPS NOT ALIGNED

##### **CAN Bus Code = 238**

- Cause: This is a real alarm that cut off the traction. It occurs at the initial alignment if the straight-ahead condition is not matched within 6sec. Throughout this 6 secs delay, the steer is not activated yet, the safety relays are open and the traction is stopped.

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## 14.2 CAN BUS “ALARMS” List

The Alarm Code List supplied by the eps-ac0 (Source Device Code 06) is the following:

6:	SERIAL ERR #1
13:	EEPROM KO
16:	LOGIC FAILURE #4
17:	LOGIC FAILURE #3
18:	LOGIC FAILURE #2
19:	LOGIC FAILURE #1
32:	VMN NOT OK
48:	MAIN CONT. OPEN
53:	STBY I HIGH
61:	HIGH TEMPERATURE
65:	MOTOR TEMPERAT.
70:	HIGH CURRENT
71:	POWER FAILURE #3
72:	POWER FAILURE #2
73:	POWER FAILURE #1
83:	BAD ENCODER SIGN
84:	STEER SENSOR KO
85:	STEER HAZARD
99:	INPUT ERROR #1
212:	MICRO SLAVE #8
218:	CLOCK PAL NOT OK
219:	STEPPER MOTOR MISM
220:	MOTOR LOCKED
221:	MICRO SLAVE #4
222:	FB POT LOCKED
223:	JERKING FB POT
225:	CURRENT GAIN
226:	NO SYNC
227:	SLAVE COM. ERROR
228:	POSITION ERROR
237:	WAITING DATA
238:	EPS NOT ALIGNED
239:	WAITING FOR TRAC
241:	ENCODER ERROR
242:	Q LINE SENSOR KO
243:	D LINE SENSOR KO
244:	GAIN EEPROM KO
245:	DATA ACQUISITION
246:	MICRO SLAVE KO
247:	CAN BUS KO
248:	S.P OUT OF RANGE
249:	F.B OUT OF RANGE
250:	MICRO SLAVE
251:	KM OPEN
252:	KS OPEN
253:	KM CLOSED
254:	KS CLOSED

# 15 RECOMMENDED SPARE PARTS

Part number	Description
C36090	Stepper motor minebea
E07161	Twin pot
C38207	Best motor 300 W AC motor and P62 DMS gear box 1:51

# 16 PERIODIC MAINTENANCE TO BE REPEATED AT TIMES INDICATED

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

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

Check the mechanical operation of the 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 requirements should be made after consulting a Zapi Agent. The supplier is not responsible for any problem that arises from wiring methods that differ from information included in this Manual.

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

Remember that Battery Powered Machines feel no pain.

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

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## 16.1 Testing the faulty detection circuitry

The material handling directive EN1175 requires periodic testing of the controller's fault detection circuitry to be checked in one of the following modes (choose the one you prefer):

- 1) Switch on the key and try to disconnect the stepper motor or the twin pot. An alarm, stopping the traction should immediately occur.
- 2) Try to disconnect the steering motor. After switching on the key an alarm stopping the traction should immediately occur as soon as the steering (or handle) wheel rotates.