



**ELECTRONIC • OLEODYNAMIC • INDUSTRIAL
EQUIPMENTS CONSTRUCTION**

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User Manual

EPS-ACW REACH TRUCK



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APPROVAL SIGNS

COMPANY FUNCTION	INIZIALS	SIGN
PROJECT MANAGER		
TECHNICAL ELECTRONIC MANAGER VISA		
SALES MANAGER VISA		

1 INTRODUCTION

Eps_acw is an electrical steering controller thought to be mounted in a “piggy back” arrangement with its steering motor (see Figure 2.1). Main application is to steer any kind of forklift trucks including counterbalanced trucks. It can work steer by wire but also steer assist (on demand). The motor technology can be standard induction motor but also brushless permanent magnet (on demand). Integrating motor and controller minimizes the wiring, reduces the installation time and improves reliability.

An electrical steering system saves the consumption given by the losses in the priority valve and in the pump motor of a hydraulics steering system increasing the efficiency of the full truck even up to 10-15%. Furthermore, it opens the door to an easy and wide customization approach. Redundancy in the microcontroller and in the sensors make possible to fulfil ISO13849 category # 3 and PLd requirements. On demand, and particularly suited for closed loop application (position control mode), the same system may be supplied with two internal encoders in the motor.

2 FEATURES

Steering controller for ACIM (BLAC on demand) motors
Digital Control using Two Microprocessors
2 Can-Bus interfaces
Both microprocessors Can Bus connected
#2 Analog Inputs configured as a Stepper Motor interface.
#1 PWM output (CNA#14): general purpose voltage controlled and overcurrent protected (max 0.7A @ $V_{batt} \leq 48V$).
#1 PWM output (CNA#10): driver of the friction device, current controlled and overcurrent protected (max 1.3A @ $V_{batt} \leq 48V$).
#2 General purpose digital inputs with inner 3.3K pull up to 13.5Vdc.
#1 Embedded Incremental Encoder interface
#1 Embedded motor thermal sensor: analog input in the range 0 to 5Vdc
#1 Embedded analog Input: in the range 0 to 5Vdc (not used)
Operating frequency: 8 kHz with center aligned PWM
External temperature range: -30 °C ÷ 40 °C
Maximum inverter temperature: 80 °C
International protection: IP65

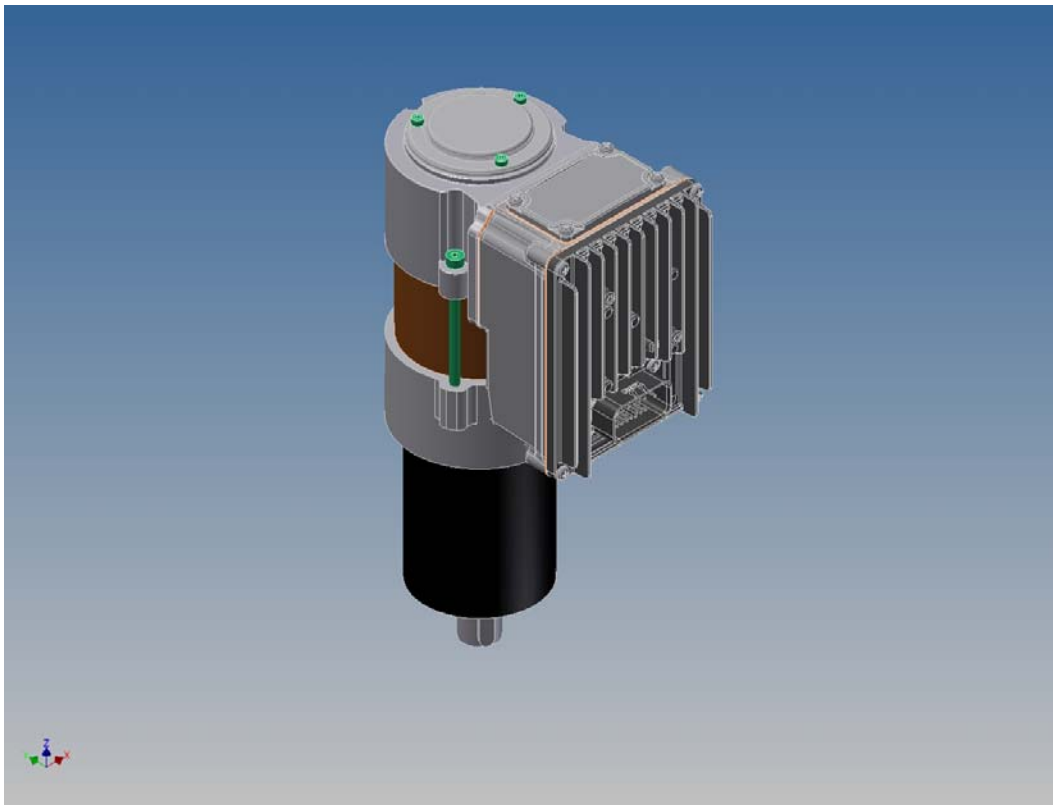


Figure 2–1

3 MECHANICAL SPECIFICATIONS

- Max Gear Box Admitted Output Torque:..... (IMS spec)
- Tightening Torque in the joint Gearbox to Truck frame:.....(IMS spec)
- Tightening Torque in the joint Gearbox to Motor flange (Ref 1):.....11 +/-1 Nm
- Tightening Torque in the Motor Flanges (Ref 2):.....11 +/- 1 Nm
- Tightening Torque in the Epsacw_heatsink-Motor joint (Ref 3): .1,5 +/- 0,2 Nm
- Tightening Torque in the 3_UVW_Motor_Cables-Epsacw joints:1,2 +/- 0,2 Nm
- Tightening Torque on the Epsacw_small_cover (Ref 5):.....1,5 +/- 0,2 Nm
- Tightening Torque on the Motor_encoder_cover (Ref 6):.....1,5 +/- 0,2 Nm

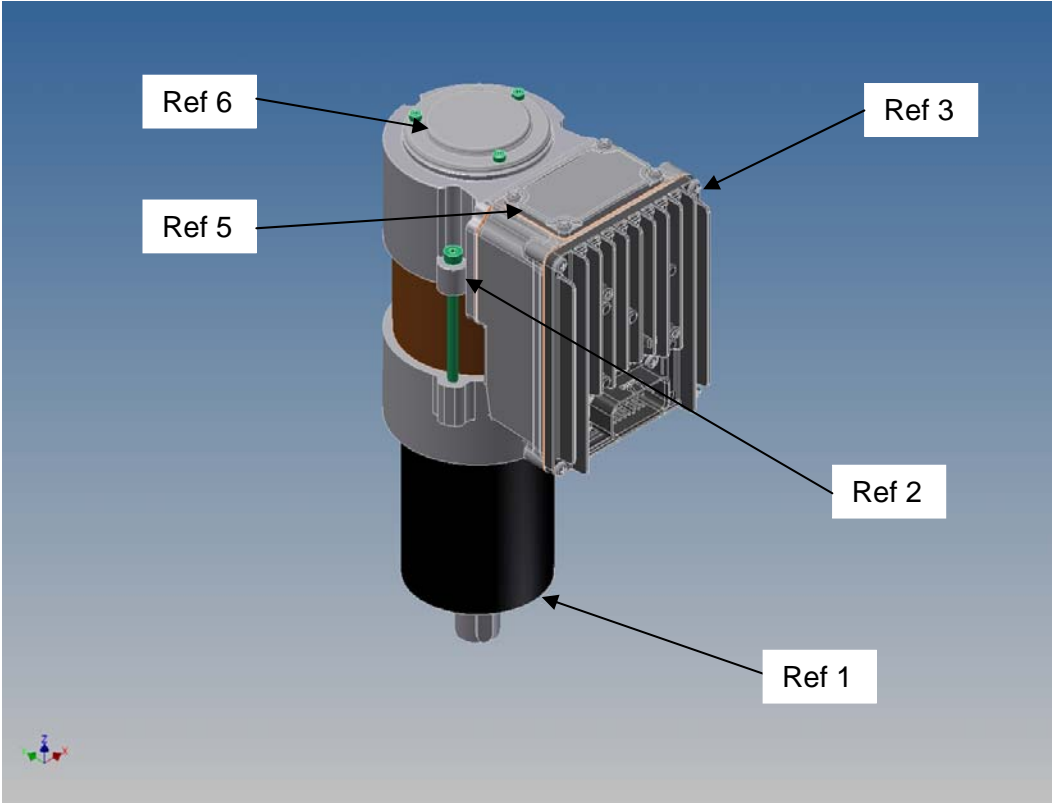


Figure 3–1

4 MECHANICAL DRAWING

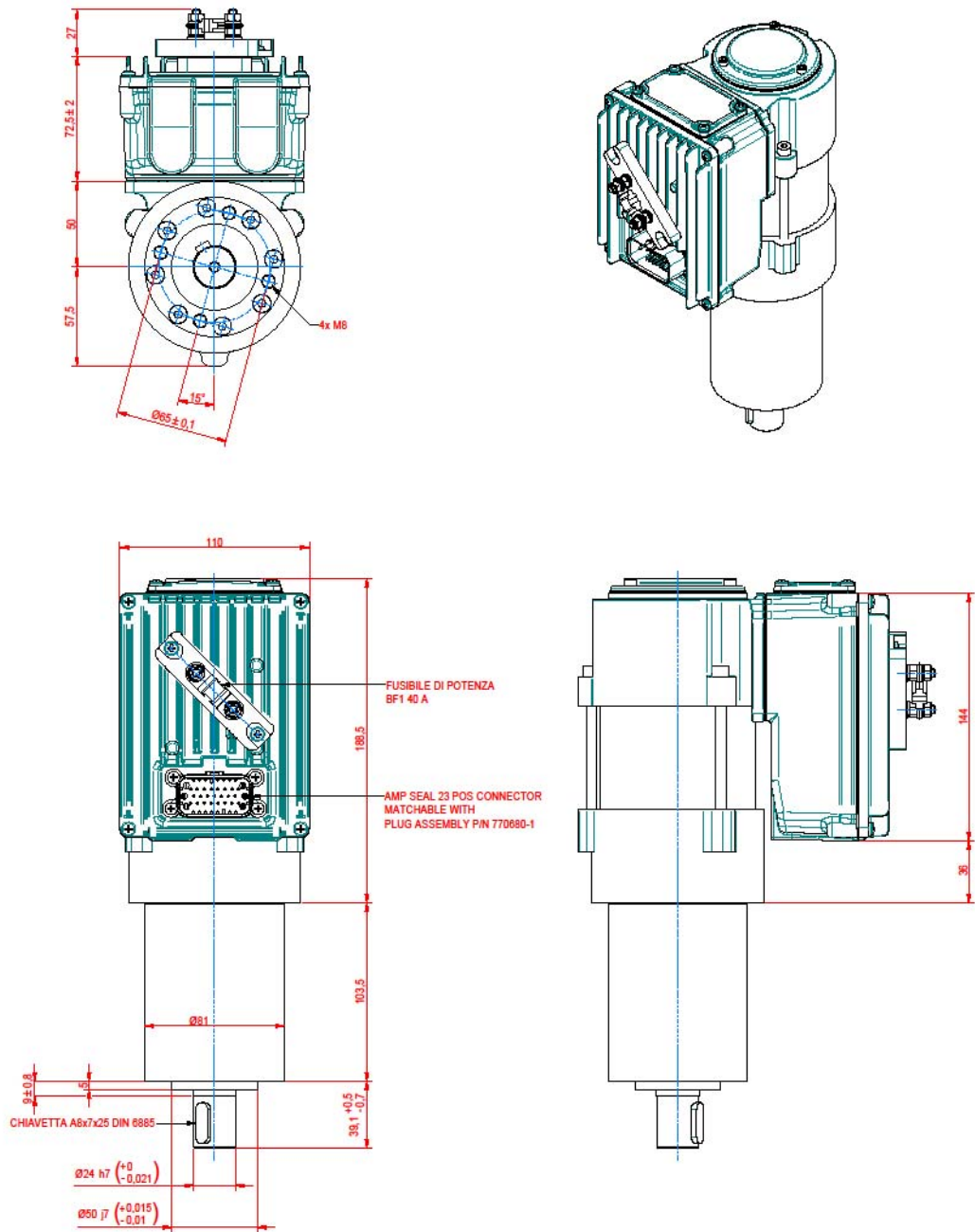


Figure 4-1

5 MOTOR AND GEAR BOX

Steering Motor:.....400W S2 1h @ 3000rpm AC induction motor
Max motor torque @ I_{max}=50A_{ac}:.....7Nm @ V_{batt}=48V
Gear Box ratio (SP81 LN):1:50
Total gears ratio (about):.....1:200
Encoder resolution*4 pulses/rev
Thermal sensor: KTY84-130

** Note: on demand, particularly suited for closed loop applications, version with two encoders same resolution is available too*

6 ELECTRICAL SPECIFICATIONS

Eps-acW F07198:.....	36/48V 70Arms
Minimum Battery Voltage:.....	35V @ Vbatt=48V
Maximum Battery Voltage:.....	65V @ Vbatt=48V
Maximum current (36/48 V):	2' (alarm after 5secs)
Logic Supply current:.....	max 200 mA @ 24 V
Minimum Input (key) Supply Voltage after start-up:.....	12 V
Power Fuse Rated Data.....	40A 58V

7 BLOCKS DIAGRAM

Below is the blocks diagram of the motor control implemented in the the epsacw. It is an Indirect Field Oriented Control but it can be turned to a sensorless motor control (on demand).

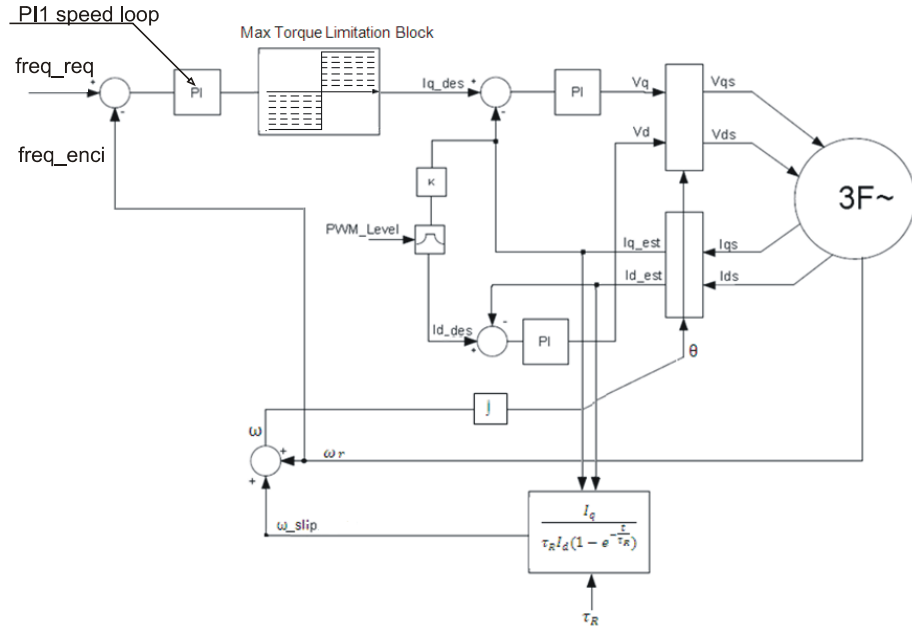


Figure 7-1 Motor Control

There are three main steering modes that it is possible to adopt for a steer application (and the blocks diagram of the external control loop will be one of three according the adopted steering mode: see 7.1 - 7.2 - 7.3 below).

7.1 Speed Control Mode (Open Loop)

In a Speed Mode (Open Loop), the steering motor speed is proportional to the speed of a tacho generator at the steering wheel. **This is the one implemented in the current application and dealt in this manual.**

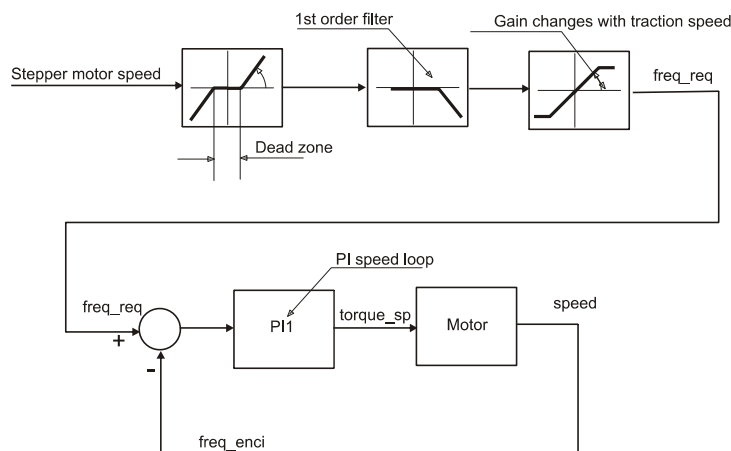


Figure 7.1-1 – Open Loop Mode Blocks Diagram

7.2 Position Control Mode (Closed Loop)

In a Position Control Mode (Closed Loop), steered wheel angle is one to one matched with the steering wheel angle.

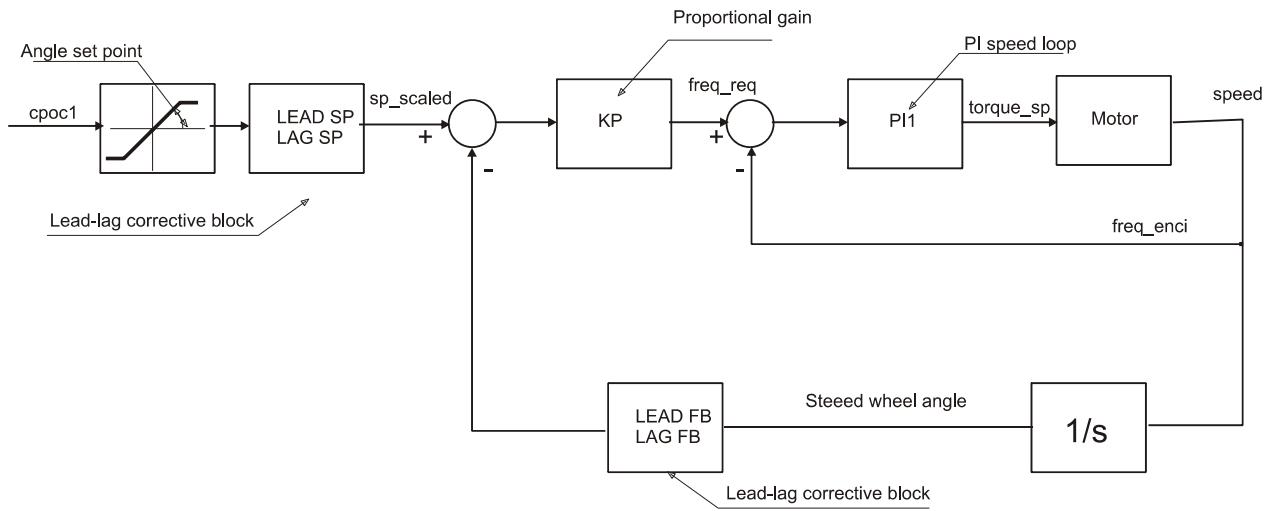


Figure 7.2-1 –Closed Loop Mode Blocks Diagram

7.3 Steer Assist Mode (Torque Assisted)

In a Steer Assist Mode (Torque Assisted), the steering motor speed is proportional to the torque of the operator on the steering handle bar.

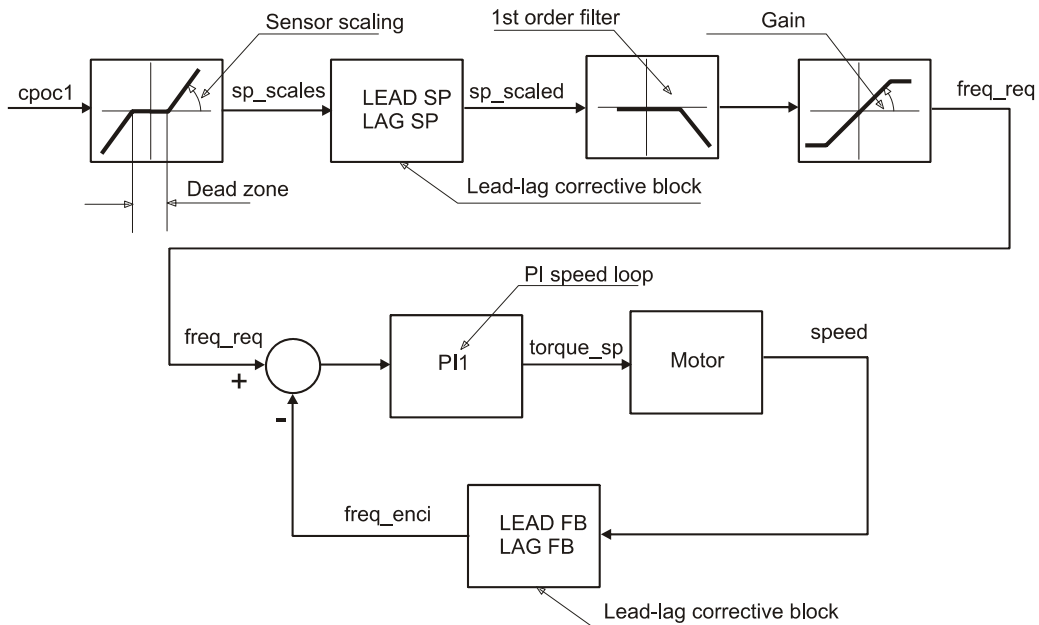


Figure 7.3-1 – Steer Assist Blocks Diagram

8 FUNCTIONS OF THE EPS-ACW

The epsacW controls the steer function of a warehouse truck in manual mode only.

8.1 Manual Mode Steering

Manual mode steering requires a command sensor in the steering wheel. This manual deals with an Open Loop mode steering system. Open Loop mode consists of a speed control: the steering motor is driven to a speed proportional to the speed of the steering wheel. So it is necessary to use a multiturn steering wheel without any mechanical limitation (no strokes). With a Multiturn steering wheel, the sensor in the steering-wheel shall be a stepper motor used as a tacho-generator (see Figure 8.1-1). Then the control will turn the steering motor moving at a speed proportional to the stepper motor speed (Open loop Mode).

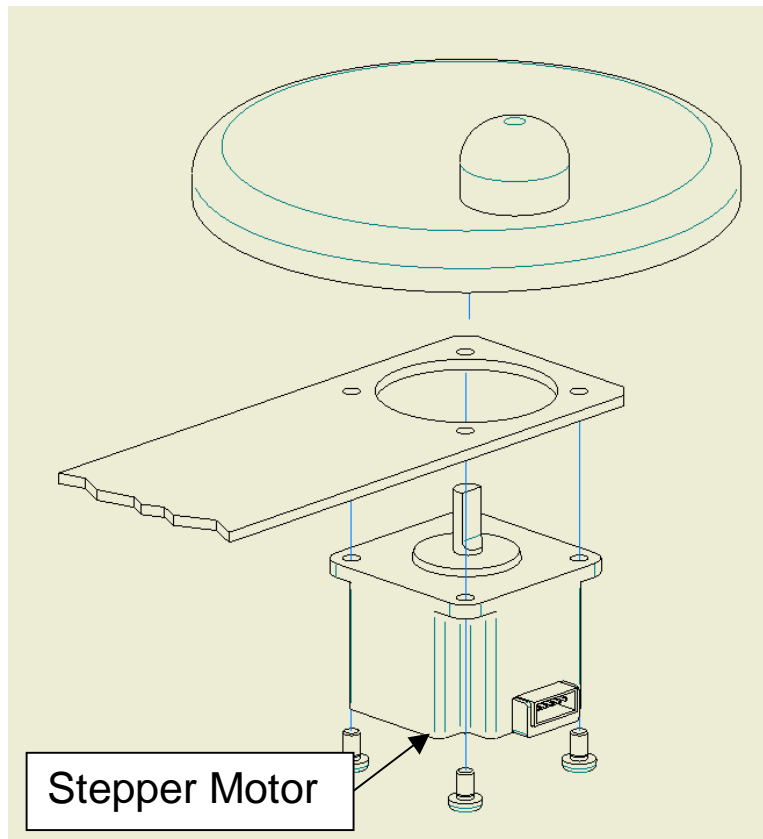


Figure 8.1-1

9 SYSTEM COMPONENTS

The integrated steering system needs the following components in order to work. The following list describes the complete equipment.

9.1 Steering Motor

The integrated steering system includes a three phase AC induction motor ($P_n=400W @ 3000rpm$) with a low resolution encoder (4pulses/rev) in the motor shaft.

9.2 Gear Box and total reduction ratio

The steering motor is coupled to a planetary three stages IMS SP81 low noise gear box with a 1:51 gears ratio. Standard arrangement typically uses a total gears ratio in the range 1:200 to 1:300. So two external gears are expected to increase the total gears ratio with a 1:4 or 1:5 factor.

9.3 EpsacW controller

It consists of a control unit working with V_{batt} in the range 36 to 48V and a maximum current limitation to 70Arms.

As the maximum torque @ $I_{max}=70Arms$ is oversized for a standard application (like a reach truck), it is possible to reduce the maximum current limitation to a lower value (see parameter MAXIMUM CURRENT) preserving the motor from overheating in case a fault (e.g. locking the gear box), turns the controller in its maximum current limitation.

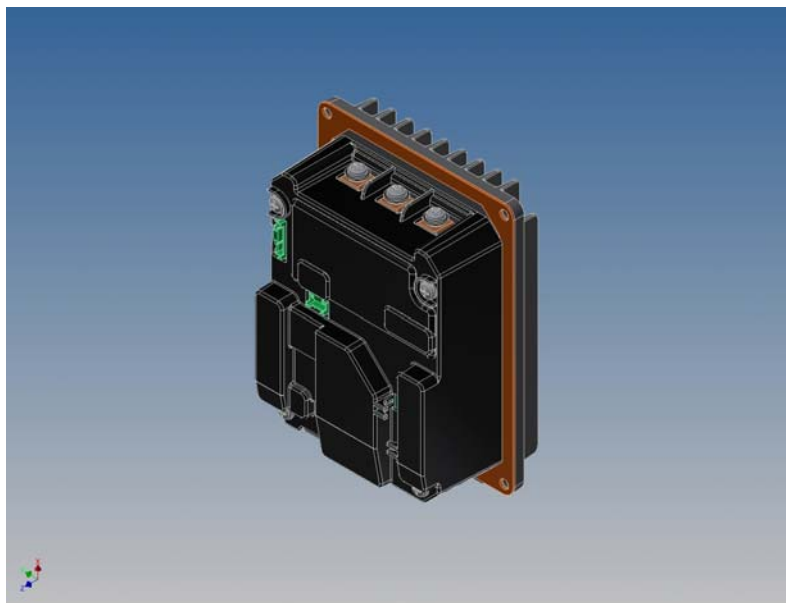


Figure 9.3–1

9.4 Sensor in the steering wheel

Only Open Loop mode (Speed control) is admitted, leading to the following configuration:

- 1) No limit, multiturn steering wheel. It asks for a command device being a stepper motor used as a tachogenerator.

9.4.1 Stepper motor

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

- 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 9.4.1-1 below). Obviously, the above information states only these parts are suited for the epsacW; no reliability evaluation is given here.

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

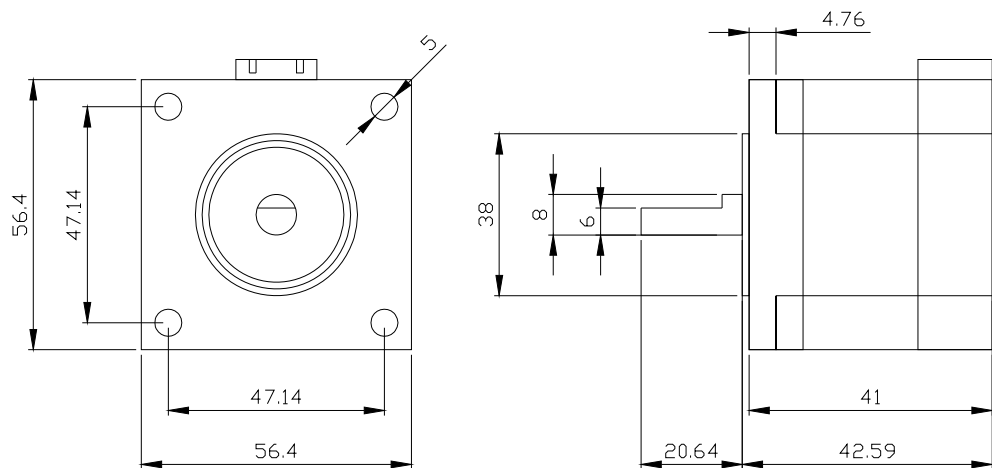


Figure 9.4.1-1

9.5 Feedback sensors

The Feedback sensors arrangement to work in Open Loop Manual mode only consists of:

- 1) Low resolution incremental encoder in the motor shaft (4pulses/rev)
- 2) Two Toggle switches in the straight ahead orientation (SW1 on CNA#12) and 90 degrees orientation (SW2 on CNA#11) of the steered wheel.

On request and with a different part number, epsacW may work also in the closed loop mode with two encoders in the motor shaft together with one (or two) straight ahead toggle switch.



This manual deals with above configuration (one incremental encoder in the motor shaft together with one or two toggle switches on the steered

wheel) working Open Loop mode.

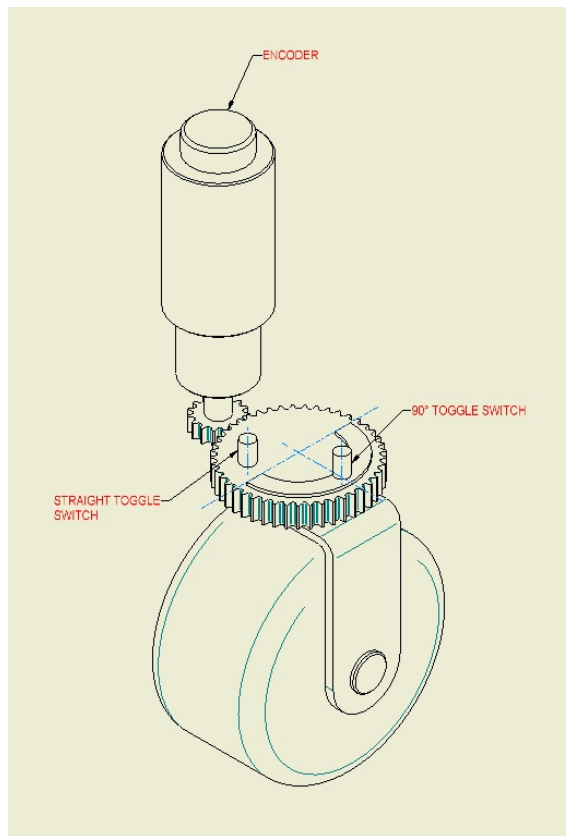


Figure 9.5-1

9.5.1 Prox switches and Cam: mounting specification

Position 0 degrees below must be meant as the orientation from the pivot point of the Drive Unit and the cam terminal closest to SW1 (with the steered wheel in the straight ahead direction) (see figure below).

On the other side, position 180 degrees must be meant as the orientation from the pivot point of the Drive Unit and the cam terminal far away from SW1 (with the steered wheel in the straight ahead direction).

Span of the steered wheel angle is in the range +/-180°. Starting from 0°, and driving the steering motor, the sign of the steered wheel angle (STEER ANGLE) is positive in the direction with positive speed (ENC SPEED >0); it is negative in the moving direction with negative speed (ENC SPEED <0).

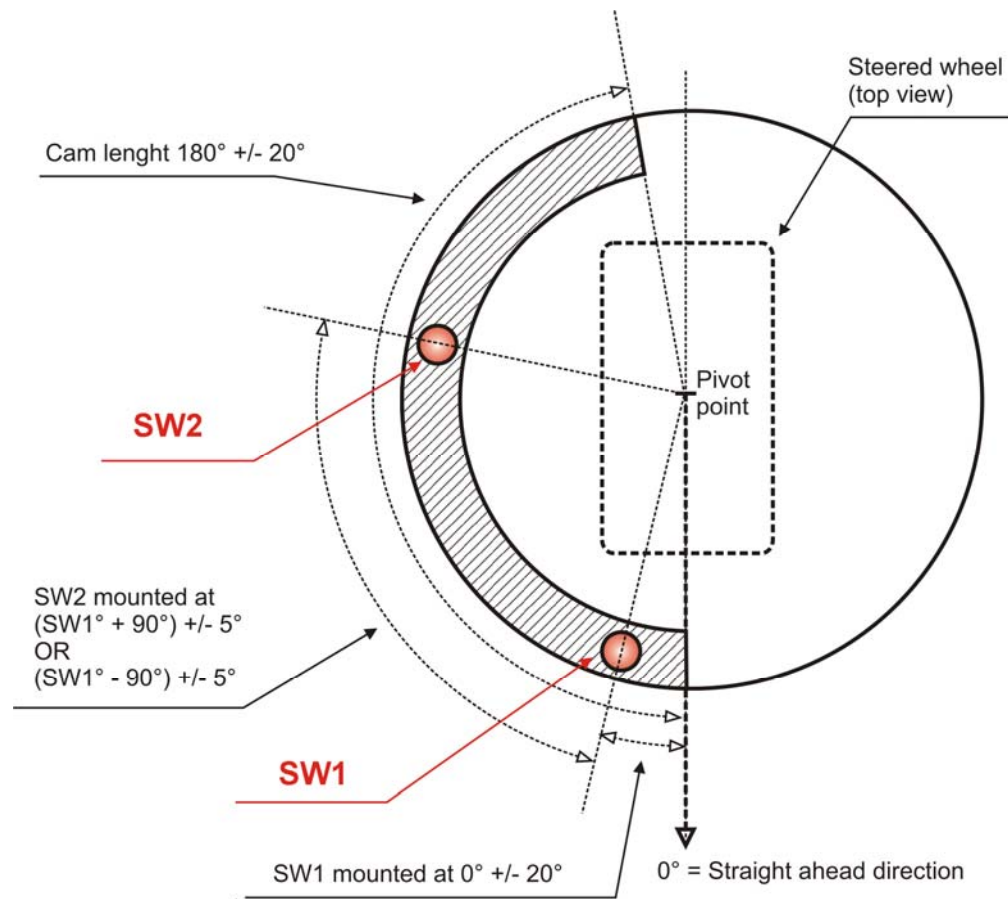


Figure 9.5.1-1

Tolerance of the SW1 (CNA#12) mounting position:.....0° +/- 20°
 Tolerance of the SW2 (CNA#11) mounting position: (SW1+90°) or (SW1-90°) +/- 5°
 Tolerance of the cam length (see also 9.5.1.1. below)180° +/- 20°

9.5.1.1 Cam length and mounting criterion

When the 90 degrees switch (SW2) is involved to limit the wheel angle (option SW2 LIMITING to ON: see 13.3.2.9), two rules should be applied when designing the cam shape (see figures 9.5.1.1-1 and 9.5.1.1-2):

- 1) Length of the cam must be the sum between max CW and max CCW angle (e.g. if the steered wheel angle must be limited to +/- 82 degrees, the cam length should be 164 degrees).
- 2) The cam should be mounted with an offset vs. the straight ahead switch (SW1). This offset must be the difference between 90° - max CW (or CCW) angle.

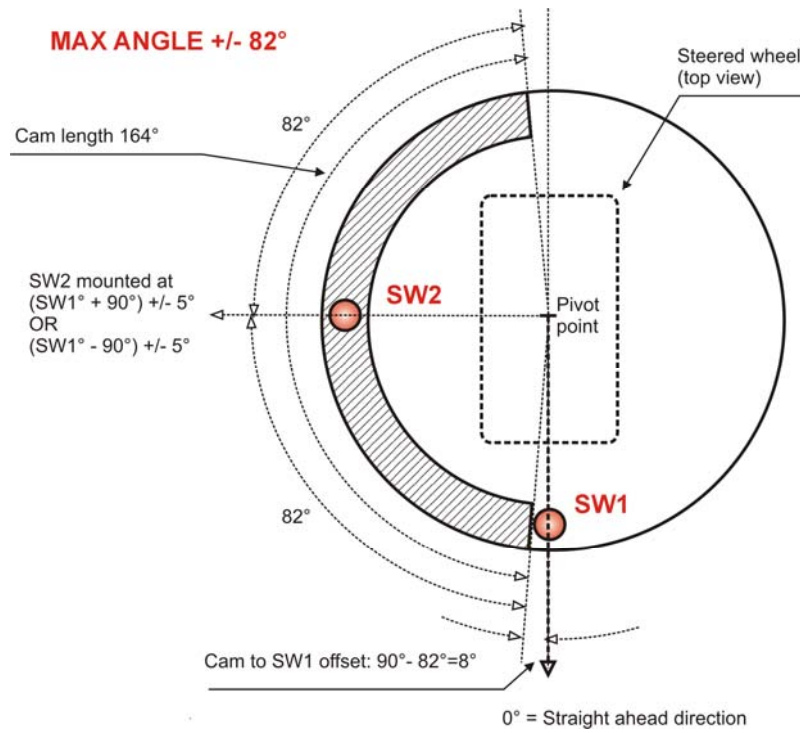


Figure 9.5.1.1-1

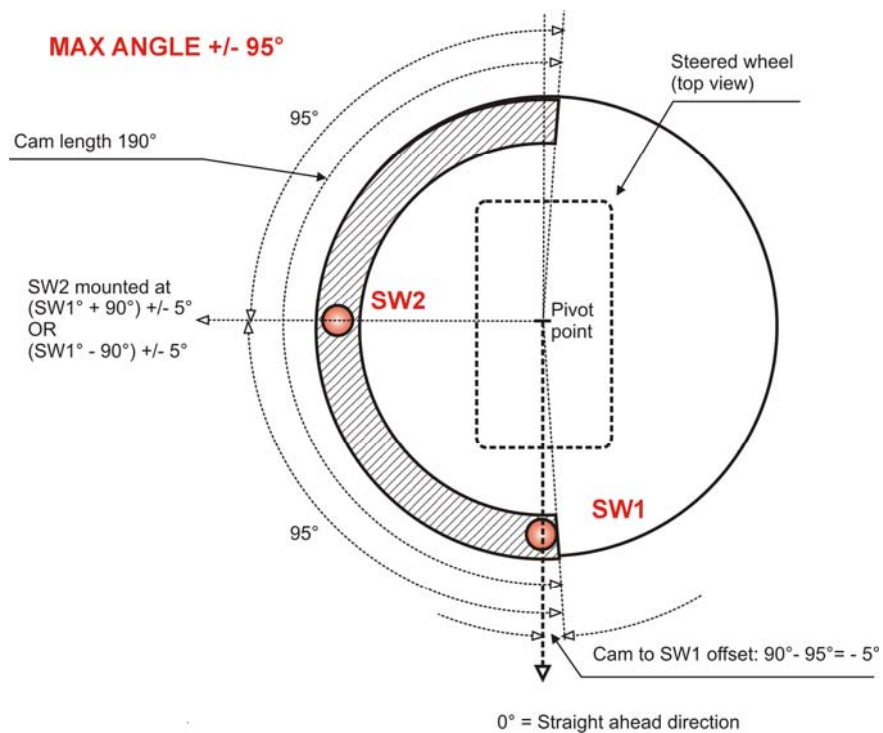


Figure 9.5.1.1-2

9.5.1.2 Straight ahead toggle switch

The straight ahead toggle switch must be of NPN type (i.e. it must connect a minus battery to CNA#12).

A possible arrangement for the straight-ahead switch (proximity switch) is shown in Figure 9.5.1.2-1 below. The proximity switch is connected to the truck frame; the Iron plate (Cam) rotates together with the steered wheel.

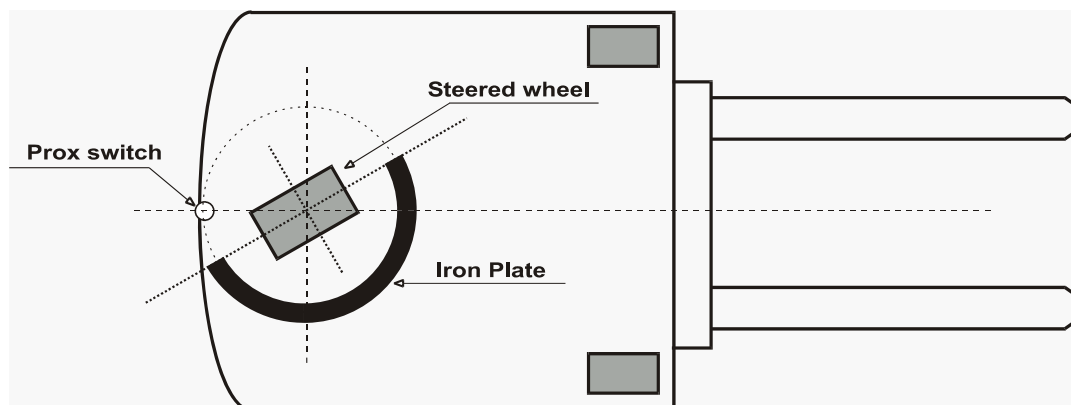


Figure 9.5.1.2-1

It is handled this way:

- 1) At key-on, the epsacW 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 (Cam with the shape shown in the sketch), provides the correct direction in which the epsacW must turn the steering motor in order the falling edge on the proximity switch is detected.

Together with the straight-ahead switch, a second toggle switch is adopted to detect when the steered wheel is in the 90 degrees limiting position. This second toggle switch must be connected to CNA#11 and GND (minus battery).

An hardware setting AUX FUNCTION 11 (see 12.4) is used to specify the toggle switches configuration (one or two toggle switches and their succession vs. angle steered wheel).

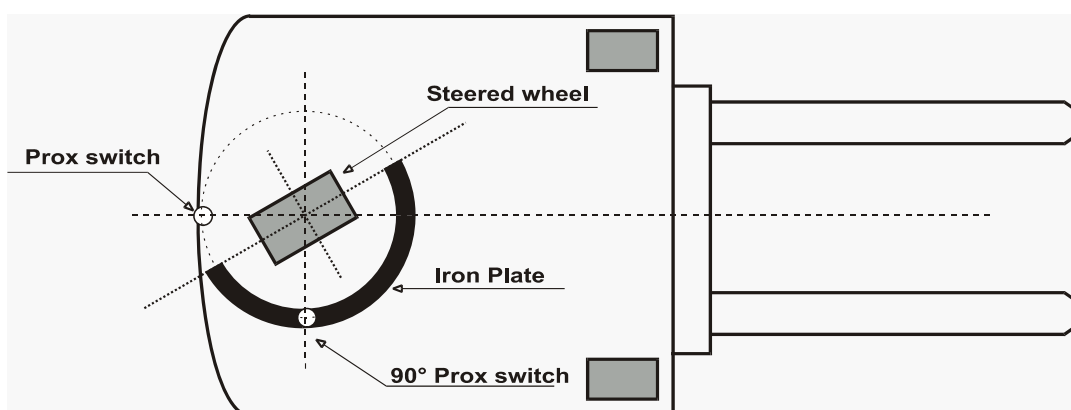


Figure 9.5.1.2-2

9.5.1.3 Feedback Encoder

One big advantage of our epsacW controller is that it can work with a cost-effective very low-resolution encoder. It consists of a multipole magnet (4 pole pairs) engaging two digital hall sensors leading to a resolution of 4 pulses/rev. That is more than enough for the angle measurement: in fact, with a total reduction ratio 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. Following this statement, we have developed, together with the Zapi AC-motors-manufacturer, 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 9.5.1.3-1). The advantages of this solution are both, money saving and effective time saving in case of encoder replacement.

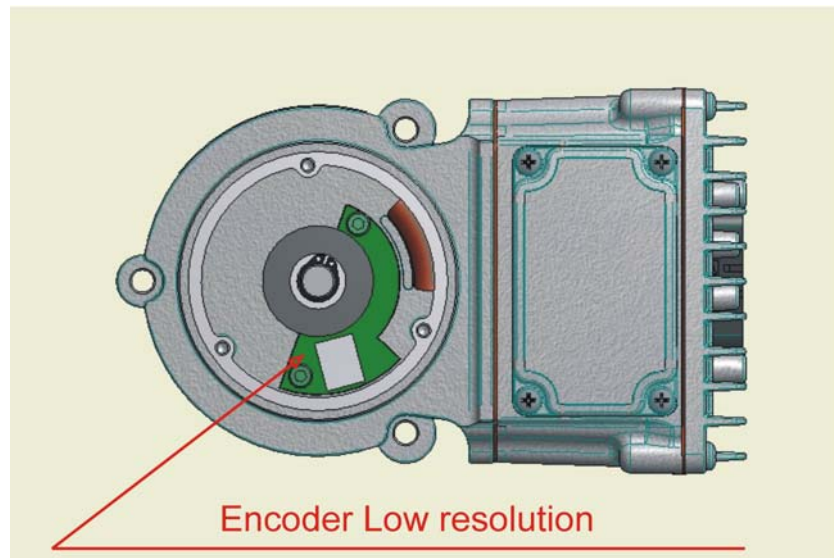


Figure 9.5.1.3-1



Note: The SW must know the encoder resolution together with the poles-pair number. The encoder resolution and the motor pole pairs (the controller can handle), will be specified in the headline of the handset showing something like:

EPSWSM 1Q NA4.98

That means:

EPSW = EpsacW steering controller

S= Open Loop Mode (Stepper motor).

M= Master Microcontroller

X= type of sensor in the TFD

1= poles pair number

Q= 4 pulses/rev encoder

NA= SW release type Nacco

4.98= SW release number 4.98

The command configuration is specified through the first two letter after EPS in the following list:

WS= Open Loop (Stepper Motor) for Warehouse Trucks

WT= Closed Loop (Twin Pot on the Tiller) for Warehouse Trucks
WW= Closed Loop (Multiturn Steering Wheel) for Counterbalanced Trucks
TA= Open Loop Torque Assist Trucks

Sixth letter specifies the Microcontroller in the following list:

M= Master Microcontroller
S= Slave Microcontroller

Seventh letter specifies the type of sensor mounted in the steering wheel in Closed Loop applications (void in Open Loop mode).

Eighth letter specifies the pole pairs of the motor:

1= 1 pole pairs (2poles)
2= 2 pole pairs (4poles)

Ninth letter specifies the encoder resolution in the following list:

Q= 4 pulses/rev
S= 6 pulses/rev
E= 8 pulses/rev
W= 16 pulses/rev
A= 32 pulses/rev
K= 48 pulses/rev
B= 64 pulses/rev

10 CONNECTING DRAWING

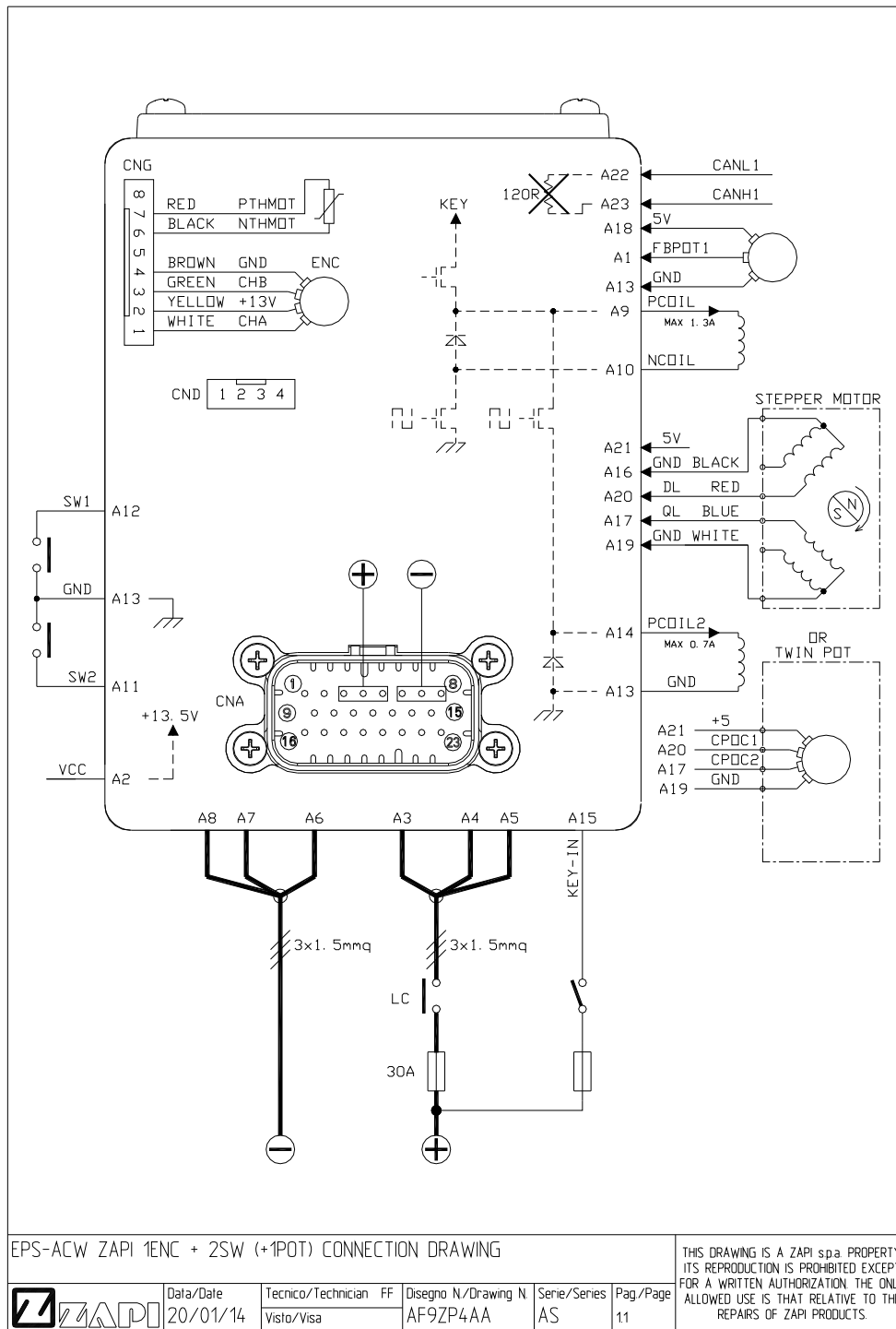
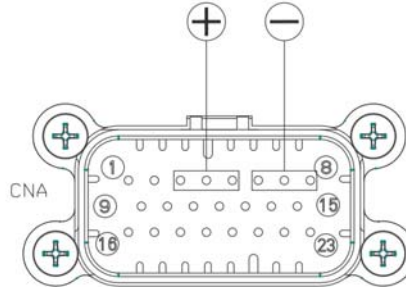


Figure 10-1

Figure 10-1 shows the connecting drawing for the epsacW suited to be used in Open Loop (multiturn steering wheel) with one encoder and two toggle switches at the Drive Unit. On customer request, release with two encoders in the motor is available too (arrangement with two encoders is strongly recommended for closed loop application => position control mode with twin pot as a command or automatic functions like automatic centering into an aisle).

10.1 Connector assignment for a configuration with 1ENC, 2SWs & 2CANs

23 poles AMPSEAL connector (CNA) assignment:



A1	FBPOT1	optional steered axle analog sensor output (0V...4.5V)
A2	VCC	13.5Vdc 200mA supply output (toggle switches or smart antennas supply voltage)
A3	PBATT	PBATT power connection
A4	PBATT	PBATT power connection
A5	PBATT	PBATT power connection
A6	NBATT	NBATT power connection
A7	NBATT	NBATT power connection
A8	NBATT	NBATT power connection
A9	PCOILS	overcurrent and short-circuit protected positive breaker for coils. A9 makes and takes Vbatt: 2Adc max @ Vbatt<=48V
A10	NCOIL	overcurrent and short-circuit protected negative breaker for a proportional coil. A10 is a PWMout: 1.3Adc max @ Vbatt<=48V
A11	SW2	DIG_IN NPN type prox switch input
A12	SW1	DIG_IN NPN type prox switch input (straight ahead)
A13	GND	NBATT logic reference
A14	PCOIL2	short-circuit protected positive breaker for a proportional coil. Cascaded with A9. A14 is a PWMout: 0.7Adc max @ Vbatt<=48V
A15	KEY IN	Key input (Logic Supply input)
A16	GND	1 ST Stepper motor GND. NBATT logic reference
A17	QL	Stepper Motor Q Line (QL) or CPOC2 0-5Vdc
A18	VDD	5Vdc 50mA supply output (PPOT positive supply for FBPOT1)
A19	GND	2 ND Stepper motor GND. NBATT logic reference
A20	DL	Stepper Motor D Line (DL) or CPOC1 0-5Vdc
A21	VDD	5Vdc 50mA supply output (PPOC positive supply for CPOC1-2)
A22	CANL1	CAN Bus 1, channel LOW (No 120 Ω termination aboard)
A23	CANH1	CAN Bus 1, channel HIGH (No 120 Ω termination aboard)



NOTE 1: For safety reason it is strongly recommended that TWO separated GND connections (CNA#16 and CNA#19) are used from the stepper motor to the epsacW.

NOTE 2: For closed loop applications (i.e. position control loop with a twin pot analog command or automatic functions like automatic centering into an aisle, release with two encoders in the motor is strongly recommended

11 INSTALLATION PROCEDURE

By setting FEEDBACK DEVICE to OPTION#4 and recycling the key, the encoder will be used in combination with one or two toggle switches to measure the steered wheel angle. The toggle switch in the straight ahead position (0 degrees) of the steered wheel is used to initialize the encoder counting.

This operation is performed through an automatic centering at key-on: the steered wheel rotates automatically until an edge is detected on the straight ahead switch. After the encoder has been initialized, it will be used for closing the loop with the commanded position.

11.1 One shot installation procedure for an arrangement without mechanical limitation

This procedure is relative to the connecting drawings Figure 10-1. It is valid also for application with electrically limited angle provided that, the steered wheel may rotate for a full revolution without mechanical limitations (i.e. without end strokes). It describes the step by step installation procedure to get the prototype working in manual mode.

For every truck released on the field, the correct installation set-up is already known (as it was determined from the test on the prototype) and so no installation procedure is required except for the quick set-up (see the quick set-up 12.2). Carry out the procedure in the following order.

- Step1** Connect the Battery to the PBATT and NBATT connections of the epsacw. Up to three wires 1.5mm² for PBATT are foreseen (same for NBATT). Total current rating for three 1.31mm² PVC wires is about 36Adc @ Tamb=40°C. Total current rating for two 1.31mm² PVC wires is about 26.5Adc @ Tamb=40°C. Total current rating for three pins of the AMPSEAL connector in the tin plated part number is 21Adc (bottleneck). An embedded I2t algorithm preserves connections from overload; instead short circuit protection is in charge of the external fuse.
- 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 an encoder in the motor shaft together with one or two toggle switches. Switch off the key after the change.
- Step4** Set special adjustment DEBUG OUTPUT to level 11 and recycle the key. (With this operation, some diagnosis are inhibited so inconsistent actions of the steering system are possible. Be prudent).
- Step5** Verify the steered wheel rotates in the correct direction according to the steering wheel. If it isn't, swap DL (CNA#17) with QL (CNA#20).

To get the system properly working it is necessary to set the encoder counting for a half steered wheel revolution together with the specification of the toggle switches arrangement (one or two toggle switches and their succession inside a complete steered wheel revolution). These setting are PULSE FOR 180 DEG and AUX FUNCTION 11 respectively. When no mechanical limitation exists on the steered wheel, the autoteaching function is the right mean for setting PULSE FOR 180DEG and AUX FUNCTION 11 (see below).

- Step6** Set special adjustment AUX FUNCTION 11 to level 0 or 1 if only one

toggle switch is adopted; set AUX FUNCTION to level 2 to 5 if two toggle switches (0 degrees and 90 degrees) are adopted. A manual fine setting of AUX FUNCTION 11 is possible too (see 12.4). If prefer you can go on with the present procedure and then AUTOTEACHING will help to properly set AUX FUNCTION 11.

- Step7** Set the special adjustment AUTOTEACHING to ON and recycle the key (see 12.6).
- Step8** The steered wheel starts turning and a ENC PULSES ACQ alarm appears in the hand set display. Two events may occurs:
- 1) After some revolutions the autoteaching procedure gets successfully ended, the steered wheel finally stops and the ENC PULSES ACQ inscription in the display changes to the collected PULSE IN 180 DEG (left side) and PLS IN HALF MOON (right side) values. In this case, setting AUX FUNCTION 11 is consistent (jump to Step 9).
 - 2) The autoteaching procedure does not get successfully ended (steered wheel continues to turn and never stops). In this case AUX FUNCTION 11 is inconsistent: if it is set to level 2 or 5 change it to level 3 or 4; if it is set to level 3 or 4 change it to level 2 or 5. Then jump back to Step 7 for performing a new autoteaching procedure.
- Step9** Set special adjustment DEBUG OUTPUT to 15 and recycle the key.
- Step10** Read the STEER ANGLE in the tester menu and turn the steered wheel in the position with a null STEER ANGLE. Watch the steered wheel orientation. If it is 180 degrees turned, change AUX FUNCTION in the following mode:
- 1) if AUX FUNCTION is set to 0, turn it to 1 (or vice versa)
 - 2) if AUX FUNCTION is set to 2, turn it to 5 (or vice versa)
 - 3) if AUX FUNCTION is set to 3, turn it to 4 (or vice versa)
- Then recycle the key.
- Step11** Now the position of the steered wheel, corresponding to a null STEER ANGLE, should be the one you expect.
- Step12** Procedure is finished. Don't forget to turn the special adjustment DEBUG OUTPUT to level 15 if never done before.
- Step13** Carry out the complete set-up description (see 12.1).

12 SETTING THE EPS-ACW

12.1 Complete set-up description

This procedure shall be executed on the prototype after the integrated steering system has been installed on the truck and the installation procedure has been performed. The complete set-up changes vs. the truck configuration. Seek your own configuration below:

12.1.1 Manual mode with the Stepper Motor

- Step1** With Zapi's support, set the correct motor parameters (see HARDWARE SETTINGS menu).
- Step2** Set the steer sensitivity. Use parameters SPEED LIMIT and SENSITIVITY (see 13.3.5.1 and 13.3.5.2).
- Step3** Set the Dynamic Numbness in open loop (steering sensitivity reduces when the truck speed increases). Use parameters SENSITIVI VS TRC and SPEED LIM VS TRC (see 13.3.5.10 and 13.3.5.11).
- Step4** Set and save hardware setting 0-POS TEACHING to ON and recycle the key.
- Step5** After the initial alignment a warning BAD STEER 0-SET occurs. In this condition, when the stepper motor is released, the steered wheel keeps the 0 degree position (null STEER ANGLE). Release the stepper motor and turn the traction moving. Roll-up and down the adjustment STEER 0-POS DEG (see 13.3.3.7) to get the truck straight travelling.
- Step6** Save STEER 0-POS DEG and recycle the key to exit the BAD STEER 0-SET warning.

12.2 Quick set-up

This procedure shall be executed on every manufactured truck. Only open loop (stepper motor) manual mode configuration is considered.

12.2.1 Stepper Motor without mechanical angle limitation

We assume the special adjustment AUX FUNCTION 11 is correctly set in its default value. Then two acquisitions are required (AUTOTEACHING to collect the encoder counting in a half revolution and 0-POS TEACHING to adjust the offset of the alignment between SW1 and the actual straight ahead direction).

- Step1** Set special adjustment AUTOTEACHING to ON and recycle the key.
- Step2** Then an autoteaching procedure automatically starts. It collects and saves the correct values for PULSE IN 180 DEG and PLS IN HALF MOON (see 13.3.3.8 and 13.3.3.9).
- Step7** Set and save hardware setting 0-POS TEACHING to ON and recycle the key.
- Step8** After the initial alignment a warning BAD STEER 0-SET occurs. Release the stepper motor and turn the traction moving. Roll-up and down the adjustments STEER 0-POS DEG (see 13.3.3.7) to get the truck straight travelling.
- Step3** Save STEER 0-POS DEG and recycle the key to exit the BAD STEER 0-SET warning.

Step4 In case the straight ahead switch SW1 is mounted very close to the straight ahead direction, 0-POS TEACHING is not required.

12.2.2 Stepper Motor with mechanical angle limitation

We assume the special adjustment AUX FUNCTION 11 together with the adjustment PULSE IN 180 DEG are correctly set in their default value. Then no quick set-up is required (otherwise see procedure 12.5 for the manual setting of PULSE IN 180 DEG).

Only one procedure (0-POS TEACHING) is suggested for the quick set-up (in case the straight ahead switch SW1 is mounted very close to the straight ahead direction, 0-POS TEACHING is not required):

- Step1** Set and save hardware setting 0-POS TEACHING to ON and recycle the key.
- Step2** After the initial alignment a warning BAD STEER 0-SET occurs. Release the stepper motor and turn the traction moving. Roll-up and down the adjustments STEER 0-POS DEG (see 13.3.3.7) to get the truck straight travelling.
- Step5** Save STEER 0-POS DEG and recycle the key to exit the BAD STEER 0-SET warning.

12.3 Sectors vs. Cam position and switches configuration

The steered wheel revolution is divided into 4 sectors (quadrants). Every sector has a length of 90 degrees.

The 90 degrees switch (SW2 connected to CNA#11) must be mounted exactly to an angle being 90 degrees vs. the straight ahead switch (SW1 connected to CNA#12). The admitted tolerance for the SW2 mounting arrangement is (SW1+90deg) or (SW1 – 90deg) +/- 5degrees.

The cam instead must be 180 degrees long. The admitted tolerance for the cam length is 180deg +/- 20degrees.

There are mainly 4 mounting arrangements for the prox switches (see figure 12.3.1-1 and 12.3.2-1 below). Two cases are considered: ENC SPEED > 0 in CCW or in CW direction.

12.3.1 Sectors when ENC SPEED is positive in CounterClockWise (CCW) direction

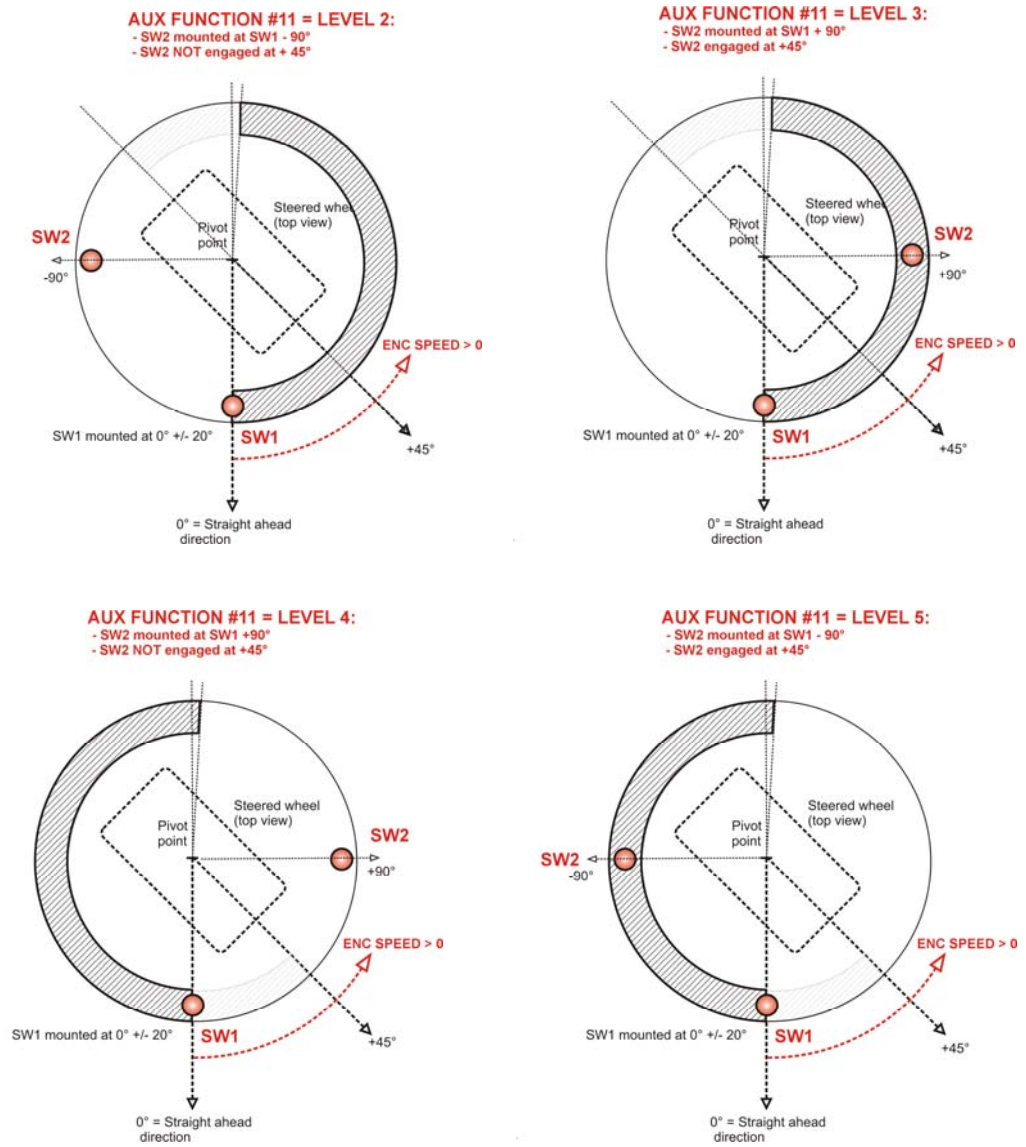


Figure 12.3.1-1: ENC SPEED > 0 in CCW direction

12.3.2 Sectors when ENC SPEED is positive in ClockWise (CW) direction

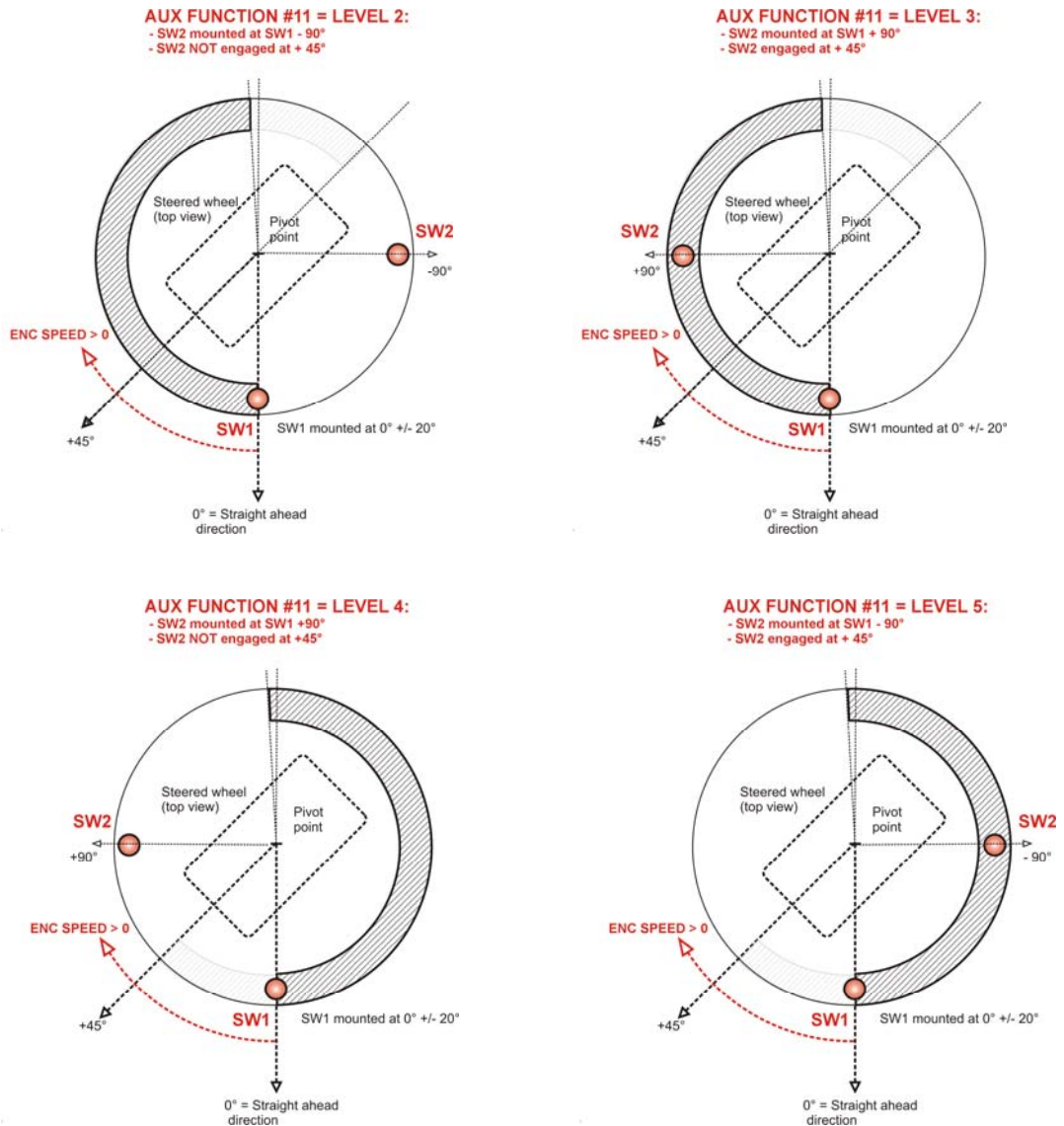


Figure 12.3.2-1: ENC SPEED > 0 in CW direction

Above figures 12.3.1-1 and 12.3.2-1 show the correct setting for AUX FUNCTION 11. Pay attention the correct setting depends by the POSITIVE turning direction of the motor (i.e. turning direction with ENC SPEED > 0 in the TESTER menu): if the motor turns positive speed in CounterClockwise Side, refer to Figure 12.3.1-1; if the motor turns positive speed in ClockWise Side, refer to Figure 12.3.2-1. If any doubt remains (or in case you are using only one switch (SW1) in the straight ahead direction), refer to the AUX FUNCTION 11 manual setting below.

12.4 AUX FUNCTION 11 manual setting

AUX FUNCTION 11 specifies the toggle switches arrangement (number of toggle

switches and their succession inside a complete steered wheel revolution). This procedure is used to find a consistent value for hardware setting AUX FUNCTION 11. Consistent value means that it is compatible with the autoteaching procedure and for passing the crossed diagnosis between encoder and toggle switches (i.e. a consistent setting permits the autoteaching successful ends and avoids alarm POSITION ERROR).

There are three couples of consistent values.

- 1) If your arrangement has one toggle switch, level 0 or 1 are both consistent.
- 2) If your arrangement has two toggle switches, level 2 or 5 could be a first consistent pair.
- 3) If your arrangement has two toggle switches, level 3 or 4 could be a second consistent pair.

So, if you have one toggle switch set AUX FUNCTION 11 to level 0 or 1.

Instead if you have two toggle switches, a selection between two pairs (above point 2) and 3)) is required.

Then, carry out the following procedure:

- 1) Set special adjustment DEBUG OUTPUT to level 11 to inhibit alarm POSITION ERROR.
- 2) Set option 90 DEG LIMIT to ON and save it and recycle the key.
- 3) Then the steered wheel makes an initial automatic centering on the 0 degrees position.
- 4) Read the STEER ANGLE in the tester menu and turn the hand wheel to get STEER ANGLE close to +45 degrees
- 5) Watch the PROX SWITCH 1 and PROX SWITCH 2 in the tester menu. They represent the state of the toggle switches connected to CNA#12 (0 degrees straight ahead switch SW1) and CNA#11 (90 degrees toggle switch SW2) respectively.
- 6) If they are equal (both ON or both OFF) the consistent pair is level 2 or 5.
- 7) If they are different (one is ON meanwhile the other one is OFF) the consistent pair is level 3 or 4.

To decide between the two values of a consistent pair, it is necessary to set AUX FUNCTION 11 to one of the two values and recycling the key.

At the next auto-centering at key-on, the steered wheel may have either the expected orientation or may be turned 180 degrees.

If it is turned 180 degrees switch from the present value to the second one.

- 1) if AUX FUNCTION is set to 0, turn it to 1 (or vice versa)
- 2) if AUX FUNCTION is set to 2, turn it to 5 (or vice versa)
- 3) if AUX FUNCTION is set to 3, turn it to 4 (or vice versa)

12.5 PULSE IN 180 DEG manual setting

Skilled person only. When the angle of the steered wheel has a mechanical limitation, it is not possible to perform the autoteaching procedure. Then it is necessary to manually set the encoder counting corresponding to 180° revolution. In order this operation is possible, a procedure for direct writing in RAM is supplied. As this is a sensitive operation (normally the steered wheel should not have mechanical limitation), we qualify skilled persons only for performing this operation. To write the PULSE IN 180 DEG directly in the parameter area, select ADDR=F602 in the READ RAM hidden menu. Then, write the encoder counting corresponding to 180 degrees wheel revolution onto the data at the right side of the display (X=.....).

This value may be calculated after knowing:

- 1) Encoder resolution (**resol** = pulses per revolution)

2) Total gears ratio (n = turns of the motor shaft corresponding to one turn of the steered wheel)

Then the encoder counting, corresponding to 180° steered wheel angle, will be:

$$\text{PULSE IN 180 DEG} = 2 * \text{resol} * n$$

This value must be transformed in four digit of a hexadecimal format.

Let us considering an example:

Suppose we have:

resol = 32 pulses/rev $n=157.25$

Then PULSE IN 180 DEG will be $2 * 32 * 157.25 = 10064$

Transformation in hexadecimal format will be:

$$10064 / 4096 = 2 \text{ with remainder} = 1872$$

$$1808 / 256 = 7 \text{ with remainder} = 80$$

$$80 / 16 = 5 \text{ with remainder} = 0$$

$$\text{Final remainder} = 0$$

Then the correct value to be written on the right side of ADDR=F602 in RAM will be X=2750.

Push the enter key (see Figure 13.2-1) to write the new X data at this location.

Now set DEBUG OUTPUT to level 1 and save the setting. DEBUG OUTPUT will be set to level 15 automatically at the next key on.



Only well trained technicians are authorized to execute the PULSE IN 180 DEG manual setting.

12.6 Autoteaching

Autoteaching is the simplest set-up procedure when the correct setting for AUX FUNCTION 11 is known and the steered wheel has not mechanical limitation. If AUX FUNCTION 11 is not correctly set, the autoteaching sequence will not successful ends.

- 1) Set hardware setting AUX FUNCTION 11 to the correct value
- 2) Set hardware setting AUTOTEACHING to ON and save the setting.
- 3) Recycle the key. The steering motor starts turning searching for the correct sequence on the straight ahead sensor.
- 4) Traction is kept stopped via a CAN Bus command from EPS.
- 5) The display of the hand set shows the alarm ENC PULSES ACQ.
- 6) When the data are correctly collected, the steering motor stops.
- 7) If PLS IN HALF MOON is not in a window from 8/10 to 12/10 PULSE IN 180 DEG, acquisition is not saved and inscription ENC PULSES ACQ in the display turns into ACQ ABORTED #1 (PLS IN HALF MOON too low) or ACQ ABORTED #2 (PLS IN HALF MOON too high).
- 8) If the couple of collected values is consistent (inscription ENC PULSES ACQ in the display does not change), the collected values are automatically saved in the adjustments PULSE IN 180 DEG and PLS IN HALF MOON
- 9) Recycle the key to finish the autoteaching procedure (setting AUTOTEACHING will be automatically turned OFF).



During AUTOTEACHING procedure, the steered wheel pivots for more than 360 degrees and so take care there is not any mechanical limitation on the steered wheel side before launching the AUTOTEACHING procedure.

13 PROGRAMMING & ADJUSTMENTS USING DIGITAL CONSOLE

13.1 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.

13.2 Description of console (hand set) & connection

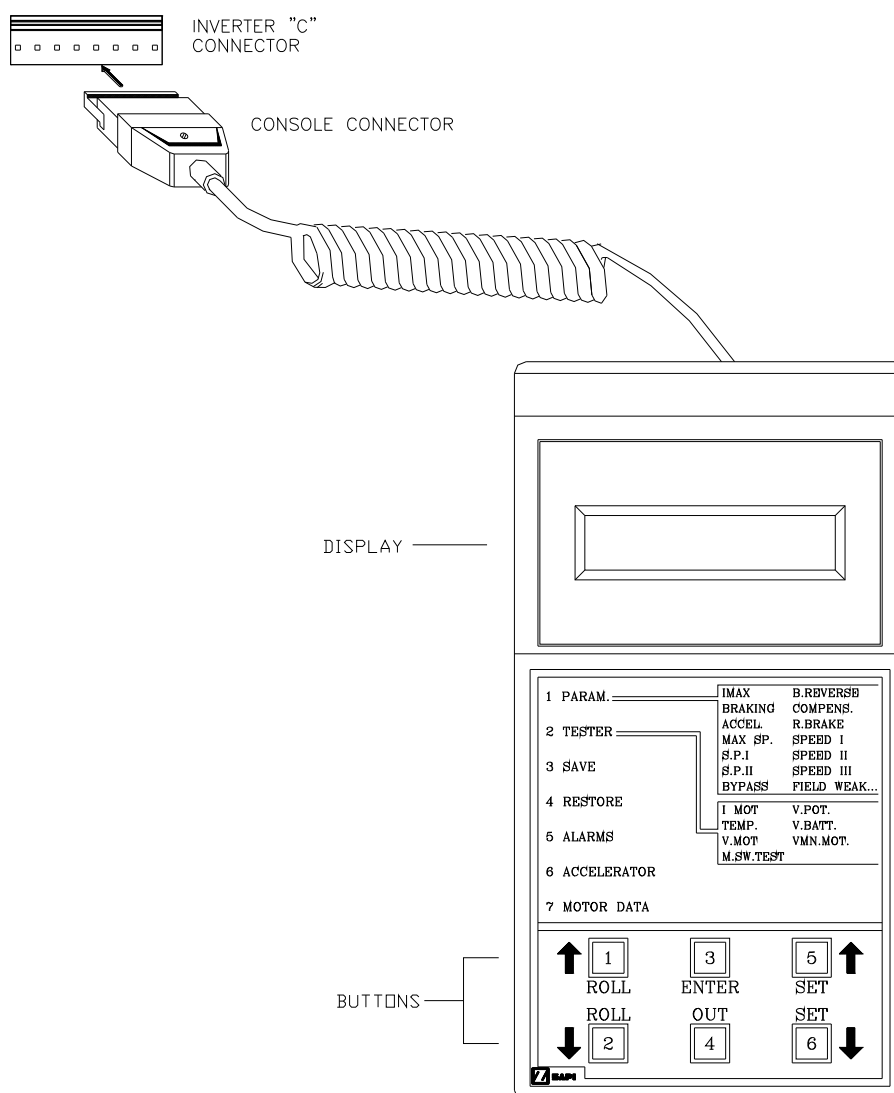


Figure 13.2-1

13.3 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 13.2-1. The orientation of the triangle indicates the way to the next function.

13.3.1 Settings in Stepper motor with Encoder and Two Toggles Switches

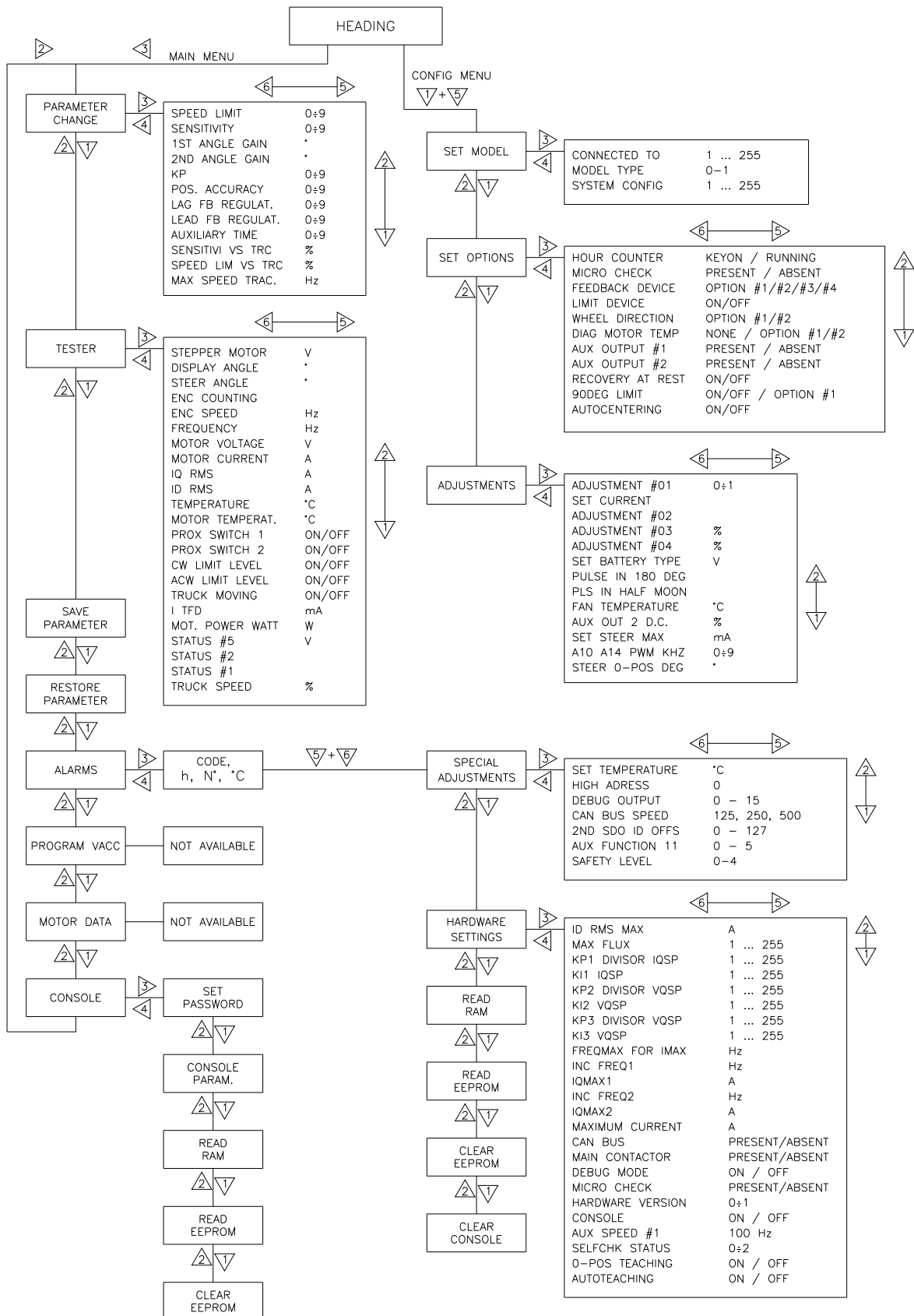


Figure 13.3.1-1

13.3.2 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 13.3.2-1).



Figure 13.3.2-1

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) FEEDBACK DEVICE

This option specifies which kind of Feedback Sensor is adopted. Only one feedback configuration is admitted:

- OPTION #4: FB ENC & ONE (or TWO) TOGGLE SWITCHES
This is the only admitted setting. It specifies that the feedback sensors consist of one or two toggle switches (in the straight and 90 degrees positions of the steered wheel) together with an encoder in the motor.

3) WHEEL DIRECTION

This option reverses the sign of the angle to be sent to the display (see STEER ANGLE and DISPLAY ANGLE in the TESTER menu).

4) DIAG MOTOR TEMP

This option enables the diagnosis of the motor temperature. When it is set ON and the motor temperature overtakes 120°, a MOTOR TEMPERAT alarm occurs.

The KTY84-130 motor thermal sensor is connected between CNG#7 and a minus battery on CNG#6 (CNG is an embedded connector).

5) AUX OUTPUT #1

This option enables the handling of the output CNA#10 (PRESENT/ ABSENT).

6) AUX OUTPUT #2

This option enables the handling of the output CNA#14 (PRESENT/ ABSENT).

7) RECOVERY AT REST

This option enables the function "alignment at the rest position". It consists of the following steps:

- 1) When releasing the stepper motor, the SW records the steered wheel angle.
- 2) Then it is expected the steered wheel angle does not change meanwhile travelling with a released stepper motor.
- 3) If the steered wheel angle tries to change for the friction in the floor, the system automatically turns back to the recorded position
- 4) If the driver moves the stepper motor meanwhile an alignment at the rest position is in progress, the alignment will be aborted

8) 90DEG LIMIT

This option enables the steered wheel angle limitation (+/- 90 degrees side to side or no limitation):

- ON: When the feedback sensor overtakes either the CW or the CCW limit (see 13.3.5.3 and 13.3.5.4 1ST ANGLE GAIN, 2ND ANGLE GAIN), the steered wheel angle shall be automatically limited.
- OFF: No steered wheel angle limitation, based on the feedback sensor value, occurs.
- OPTION#1 when set to option #1 the limit of the side to side steered

wheel angle are commanded via CAN Bus (display).
Recycle the key after the setting.

9) SW2 LIMITING

This option enables the function to involve the 90 degrees switch (SW2) to limit the max steered wheel angle.

When it is set to OFF, the max steered wheel angle will be limited when the encoder counting reaches the 1ST (2ND) ANGLE GAIN.

When it is set ON, the steered wheel angle will be limited when two conditions occur:

- a) the encoder counting reaches the 1ST (2ND) ANGLE GAIN
- AND
- b) the 90 degrees switch (SW2) toggles.

13.3.3 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 13.3.3-1 below).

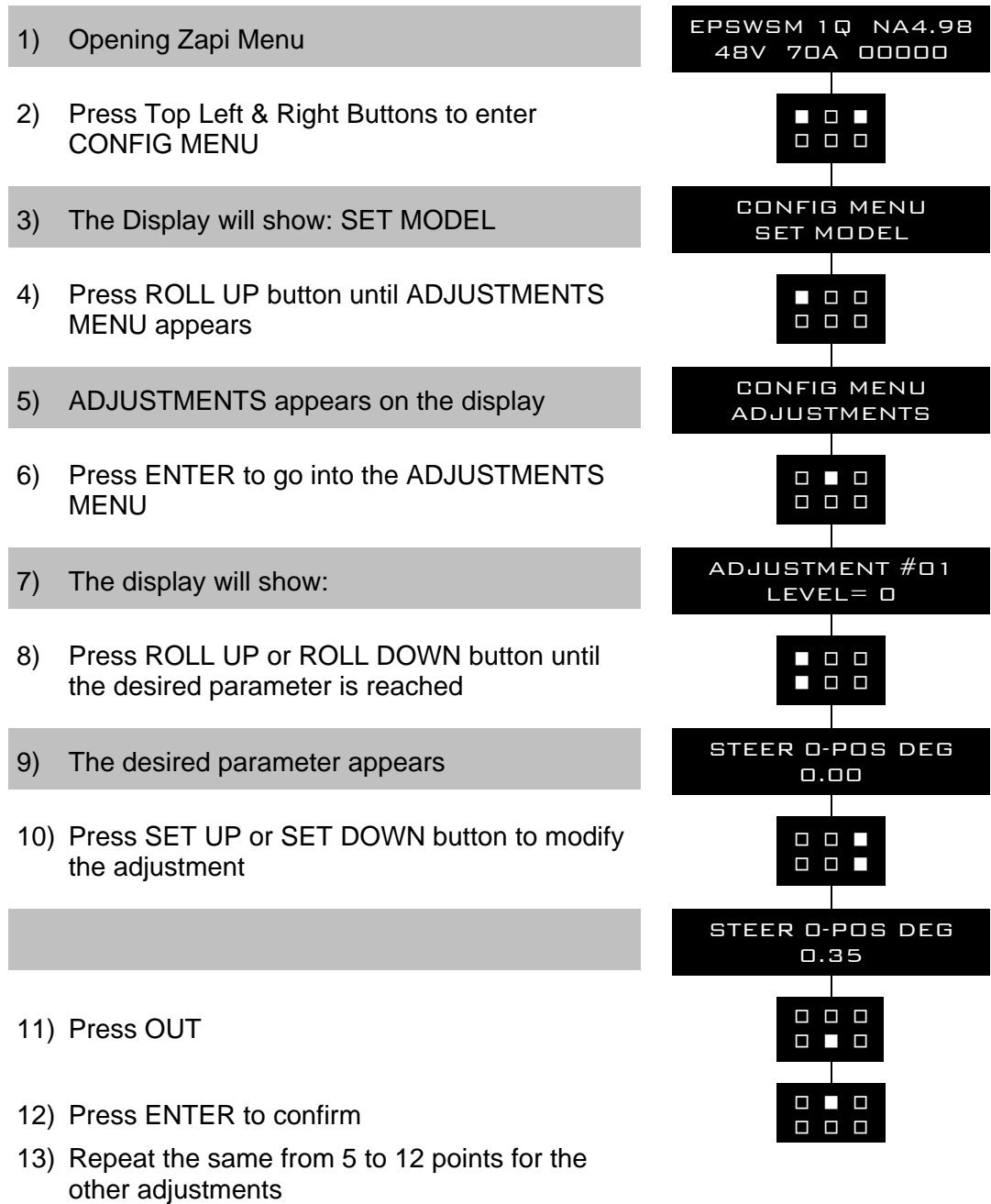


Figure 13.3.3-1

- 1) **ADJUSTMENT #01**
This setting is used to acquire the motor resistance (see 13.3.3.3 ADJUSTMENT #2).
- 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 (Zapi adjusted) 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. Never set SET BATTERY TYPE lower than 36V for a 36/48V controller.
- 7) **STEER 0-POS DEG**
Degrees with two decimal digits and sign. This adjustment is used to compensate the offset between the straight ahead switch and the real straight ahead direction in the truck. It is set in steps of 0.351 degrees against the straight ahead switch direction.
Use the 0-POS TEACHING procedure to properly set STEER 0-POS DEG.
- 8) **PULSE IN 180DEG**
This adjustment shows the encoder counting corresponding to a half steered wheel revolution. It is an important setting especially for applications without steered wheel angle limitation. Procedure for PULSE IN 180DEG consists of collecting the encoder counting corresponding to a full steered wheel revolution and then dividing that to a half. To do that two ways are available: autoteaching (see 12.6), and PULSE IN 180DEG manual setting (see 12.5). Autoteaching procedure automatically saves the new counting on PULSE IN 180DEG. As an alternative, PULSE IN 180DEG may be also manually written and saved in EEPROM (see 12.5).
- 9) **PLS IN HALF MOON**
This adjustment show the encoder counting corresponding to a partial steered wheel revolution (about a half) occurring between two falling edges of the straight ahead sensor: the first falling edge is generated with the incidence of the first iron plate (cam) limit; the second falling edge is generated with the incidence of the second iron plate (cam) limit (see Figure 8.5.1-1). It is an important setting for applications without steered wheel angle limitation. Procedure for PLS IN HALF MOON consists of collecting the encoder counting corresponding to the angle covered by the half moon cam. To do that use autoteaching (see 12.6). Autoteaching procedure automatically saves the new counting on PLS IN

HALF MOON.

10) FAN TEMPERATURE

Epsacw drives the fan for cooling the entire system. When the temperature in the epsacw overtakes this setting, the fan must be switched on.

11) OUX OUT 2 D.C.

This parameter sets the max PWM (in percentage of the full conduction) on output CNA#14.

12) SET STEER MAX

It sets the max current in the fan connected to CNA#10.

13) A10 A14 PWM KHZ

It sets the frequency of the PWM in the loads connected to CNA#10 and CNA#14.

14) AUX VOLTAGE #1

(Factory adjusted). This is the self-acquired offset value of the stepper motor line connected to CNA#20. The default value is 2.500 mV and can be re-acquired by rolling the DEBUG OUTPUT to 0 (see 13.3.7.3).

15) AUX VOLTAGE #2

(Factory adjusted). This is the self-acquired offset value of the stepper motor line connected to CNA#17. The default value is 2.500 mV and can be re-acquired by rolling the DEBUG OUTPUT to 0 (see 13.3.7.3).

13.3.4 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 13.3.4-1 below).

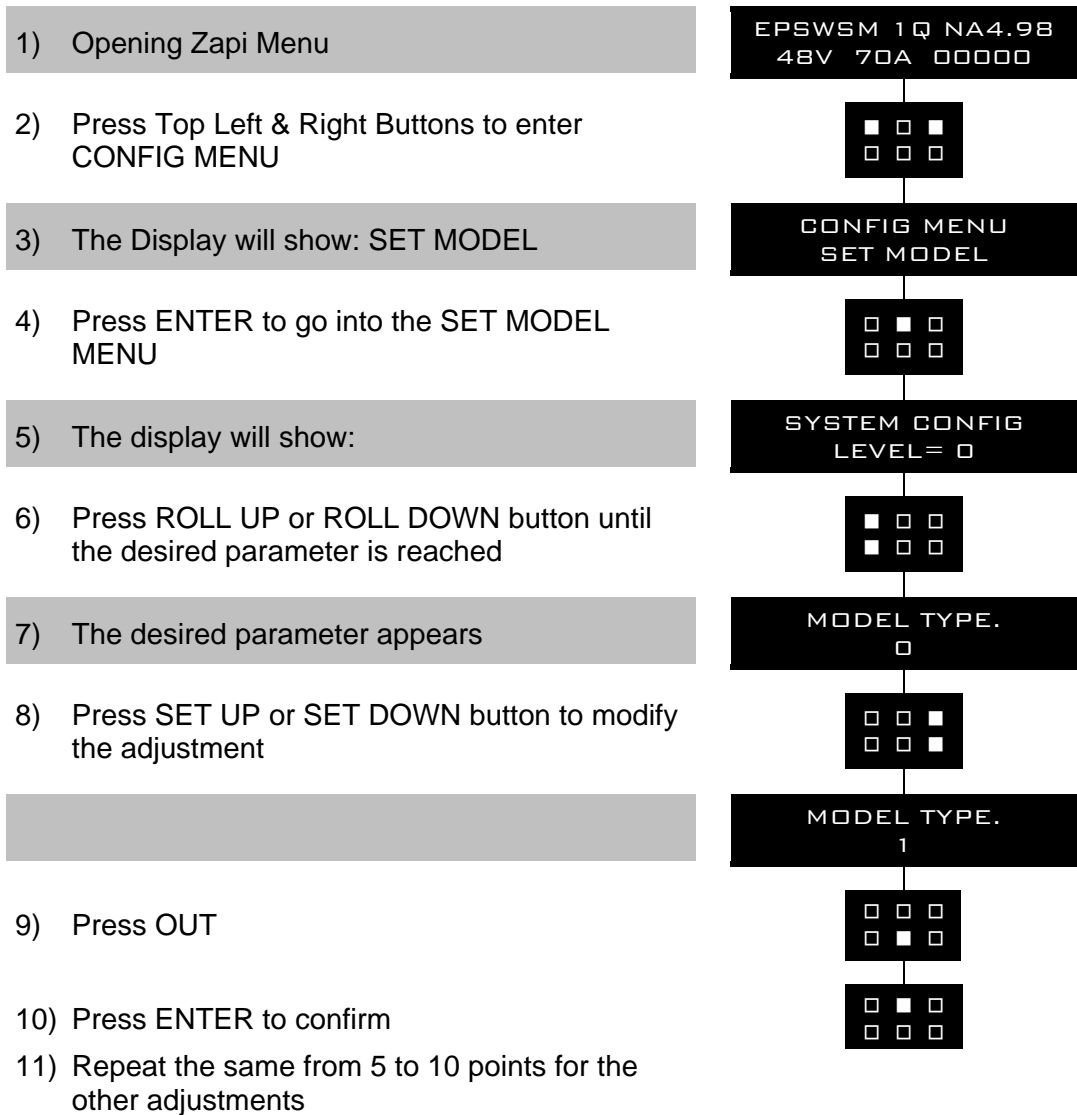


Figure 13.3.4-1

1) 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 epsacw it is possible to communicate with a remote Zapi unit. Every Zapi unit has its own identification number (e.g. epsacw master uC is 6; traction master uC is 2).

By setting CONNECTED TO to 2, the hand set will be virtually connected to the traction controller.

2) MODEL TYPE

Not implemented. 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 epsacw 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.

3) 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). Only LEVEL 0 (open loop mode) is implemented.

- 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. This setting specifies also, that a feedback sensor is present and it will be used for the automatic centering at key-on, for the angle measurement, for the max angle limitation and for the recovery at rest. The FEEDBACK DEVICE option (see 13.3.2.2) specifies which kind of feedback sensor is adopted.

13.3.5 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.

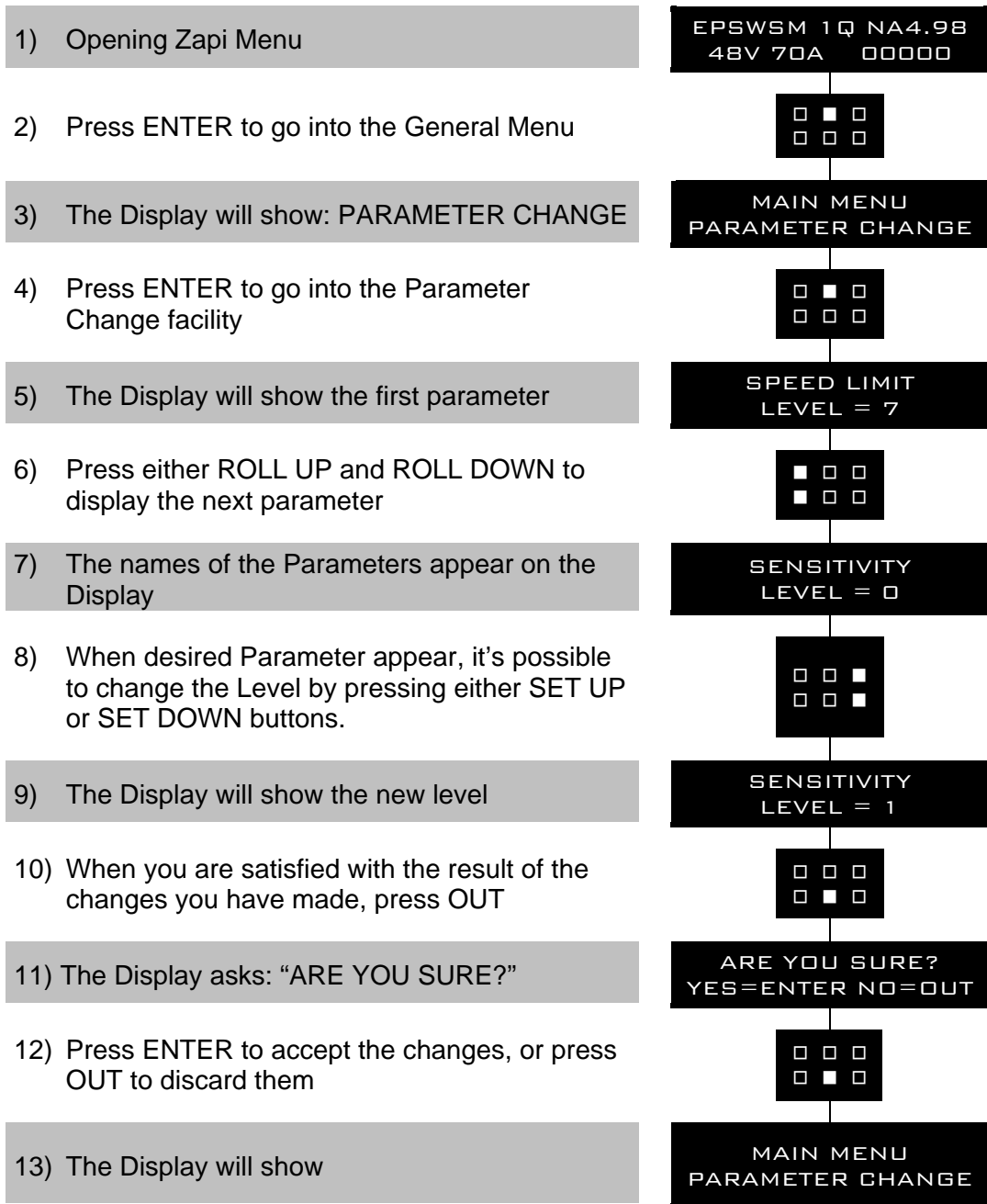


Figure 13.3.5-1

1) SPEED LIMIT

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

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) 1ST ANGLE GAIN

This parameter sets the max angle in the direction with positive STEER ANGLE. It is effective only in case the steered wheel angle is limited (see option 90DEG LIM).

4) 2ND ANGLE GAIN

This parameter sets the max angle in the direction with negative STEER ANGLE. It is effective only in case the steered wheel angle is limited (see option 90DEG LIM).

5) KP

Level 0 to 9. It is used to set the proportional contribution to a PID algorithm for the closed loop control. When in open loop mode (stepper motor) this parameter is used only for the closed loop secondary functions (i.e. angle limitation and recovery at rest). These functions are performed at very slow motor speed in order they are not safety relevant 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.

6) POS ACCURACY

Level 0 to 9. It is used to set the proportional contribution to a PID algorithm for the closed loop control. When in open loop mode (stepper motor) this parameter is used only for the closed loop secondary functions (i.e. angle limitation and recovery at rest). These functions are performed at very slow motor speed in order they are not safety relevant 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. KP and POS. ACCURACY are a coarse and a fine contribution to the same setting.

7) LAG FB REGULAT

Level 0 to 9. It is used to set the integral (lag) contribution to a PID algorithm for the closed loop control (i.e. angle limitation and recovery at rest). 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).

8) LEAD FB REGULAT

Level 0 to 9. It is used to set the derivative (lead) contribution to a PID algorithm for closed loop control (i.e. angle limitation and recovery at rest). 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).

9) 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.
- LEVEL 9: Long application of the stand still torque.

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

10) SPEED LIM VS TRC

Percentage 10% to 100%. 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. SPEED LIM VS TRC 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. SPEED LIM VS TRC to 100% means no attenuation of the scaling factor with the truck speed (no limitation on the steering motor speed). SPEED LIM VS TRC to 20% means the scaling factor is attenuated to 0.2 at full truck speed. SPEED LIM VS TRC to 10% means the scaling factor is attenuated to 0.1 at full truck speed (steer less sensitive). Obviously, to perform the Dynamic Numbness compensation, it is necessary to know the drive speed and so the epsacW must be CAN Bus connected.

11) SENSITIVI VS TRC

Percentage 10% to 100%. 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. SENSITIVI VS TRC 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.
 SENSITIVI VS TRC to 100% means no attenuation of the scaling factor with the truck speed (no limitation on the steering motor speed).
 SENSITIVI VS TRC to 20% means the scaling factor is attenuated to 0.2 at full truck speed.

SENSITIVI VS TRC to 10% means the scaling factor is attenuated to 0.1 at full truck speed (steer less sensitive).

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.

12) MAX SPEED TRAC

This parameter sets the frequency in Hertz corresponding to the 100% of the traction speed. When the traction speed is higher equal than MAX SPEED TRAC, epsacw considers the traction speed is full speed.

13.3.6 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.

Here we have the parameters for the motor control.

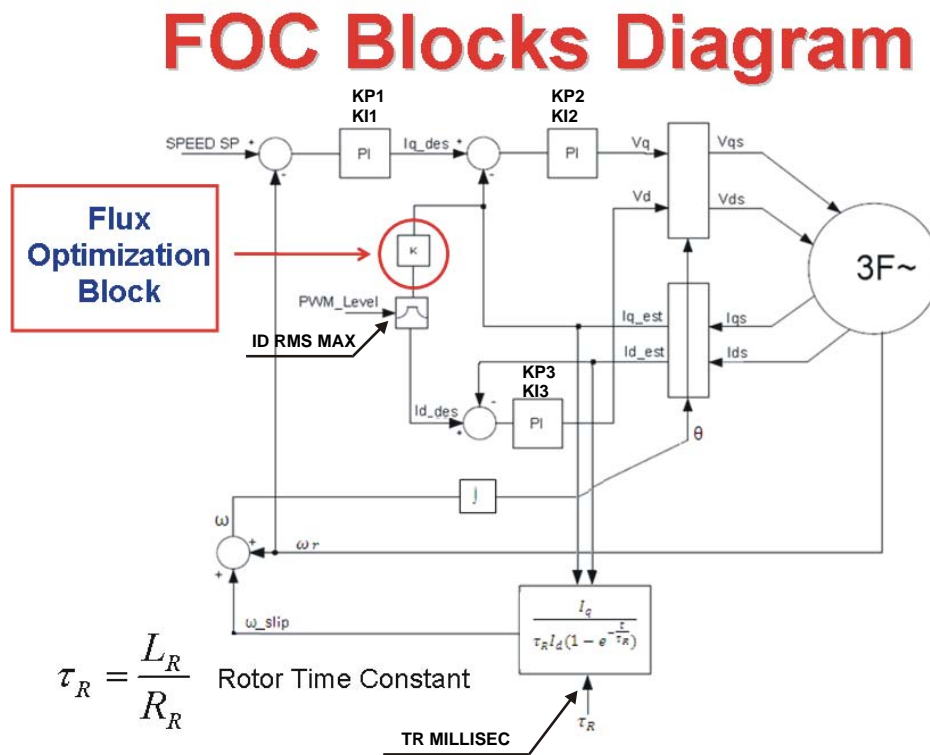


Figure 13.3.6-1

1) ID RMS MAX

Maximum direct current in Arms. Factory adjusted.

2) MAX FLUX

Maximum linked flux (peak value in milliweber) in the delta model. Typically it is given by the formula $159 \cdot V_{batt} / \text{corner_freq}$. Not used.

3) TR MSEC

Rotor time constant milliwbeber in stall condition. Factory adjusted.

- 4) **KP1 DIVISOR IQSP**
Proportional divisor (PI) for the speed loop. Factory adjusted..
- 5) **KI1 IQSP**
Integral factor (PI) for the speed loop. Factory adjusted.
- 6) **KP2 DIVISOR VQSP**
Proportional divisor (PI) for the IQ loop. Factory adjusted.
- 7) **KI2 VQSP**
Integral factor (PI) for the IQ loop. Factory adjusted.
- 8) **KP3 DIVISOR VDSP**
Proportional divisor (PI) for the ID loop. Factory adjusted.
- 9) **KI3 VDSP**
Integral factor (PI) for the ID loop. Factory adjusted

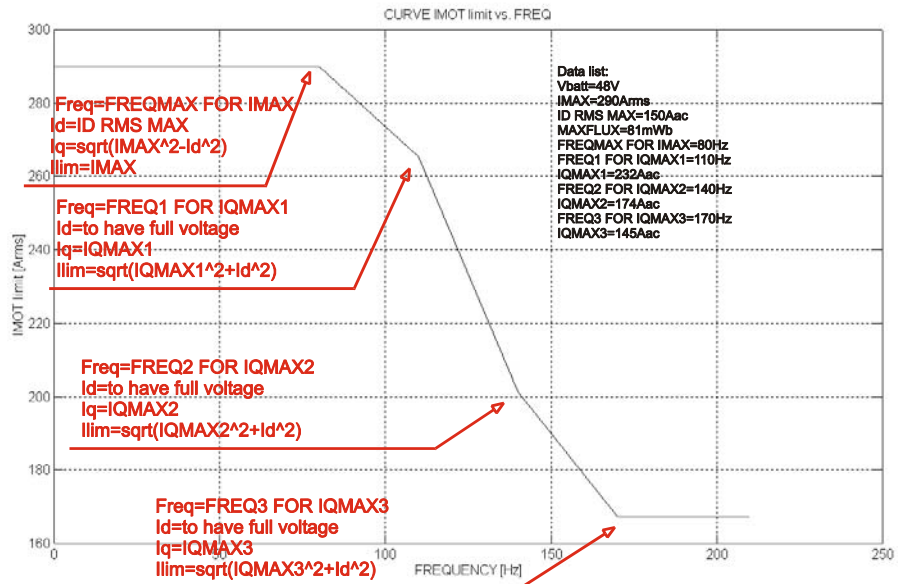


Figure 13.3.6-2

- 10) **FREQMAX FOR IMAX**
Current in the steering motor is limited to the MAXIMUM CURRENT value up to this frequency. At higher frequency, I_{max} is limited to a lower value following the weakening torque profile of Figure 13.3.6-2. Factory adjusted.
- 11) **INC FREQ1**
When the frequency in the steering motor is FREQMAX FOR IMAX + INC FREQ1, the quadrature current is limited to IQMAX1 below. Factory adjusted.
- 12) **IQMAX1**
Maximum quadrature current at a motor frequency of FREQMAX FOR

IMAX+INC FREQ1. (Meantime the direct current will be limited by the full motor voltage). Factory adjusted.

13) INC FREQ2

When the frequency in the steering motor is FREQMAX FOR IMAX + INC FREQ1+INC FREQ2, the quadrature current is limited to IQMAX2 below. Factory adjusted.

14) IQMAX2

Maximum quadrature current at a motor frequency of FREQMAX FOR IMAX+INC FREQ1+INC FREQ2. (Meantime the direct current will be limited by the full motor voltage). Factory adjusted

15) MAXIMUM CURRENT

Imax can be limited lower equal than the absolute maximum current (70Arms) with this parameter.

16) CAN BUS

This setting enables the CAN bus communication with the traction controller. In case it is set ABSENT, at the next key on, the steering system turns at rest as soon as the stepper motor is released and the dynamic numbness vs. trac speed is disabled.

17) MAIN CONTACTOR

In case the Main Contactor make and take the +B to the epsacw, it must be set ON (default value). In case the epsacw is directly connected to the battery terminal (+B), it must be set OFF.

18) DEBUG MODE

This adjustment enables the debug frames to be released on the CAN BUS communication system. Zapi reserved.

19) HARDWARE VERSION

This is just an evidence of the HW release is aboard. This is protected against being written.

20) CONSOLE

This adjustment enables/disable the communication with the Zapi hand set.

21) AUX SPEED #1

This adjustment sets the max steering motor speed in hertz.

22) SELFCHK STATUS

This option enables a selfchecking routine to test the motor and power drives (selfcheck#1) or the encoder and trasmission (selfcheck#2).

- 1: At the next key on, an alarm SELFCHECK #1 occurs and a selftest routine is raised to check the functionality of the motor and power drives. A fixed 14.7Adc current is injected and measured and the resistances at the motor terminals are measured. The results of the selfcheck #1 are shown real time in the TESTER menu reading STATUS #1.
- 2: At the next key on, an alarm SELFCHECK #2 occurs and a selftest routine is raised to check the functionality of the

encoder and transmission. A fixed speed of 25Hz is commanded in the motor and the speed and current in the motor are measured. The results of the selfcheck #2 are shown real time in the TESTER menu reading STATUS #2.

23) 0-POS TEACHING

This option (On/Off) is used to launch the procedure to properly set adjustment STEER 0-POS DEG. Turn it on and recycle the key. Then, as soon as the driver stops turning the steering wheel, the steered wheel will be continuously commanded to the straight ahead direction (recovery at 0 degrees).

With the steered wheel locked at the 0 degrees direction, check the truck is really travelling straight ahead direction; in case it isn't, roll up or down adjustment STEER 0-POS DEG until the truck travels straight ahead direction. Then save STEER 0-POS DEG and recycle the key.

24) AUTOTEACHING

This option (On/Off) is used to launch the autoteaching procedure (see 12.6). Take care there is not mechanical angle limitation before to turn it on. Then recycle the key and the steering motor starts an automatic sequence to collect the PULSE IN 180 DEG (see 13.3.3.8) and PLS IN HALF MOON (see 13.3.3.9). If the collected couple is consistent (PLS IN HALF MOON stays inside the window from 3/4 to 6/4 of PULSE IN 180DEG) they are automatically saved on the settings PULSE IN 180 DEG and PLS IN HALF MOON. If the autoteaching procedure is in progress, warning ENC PULSES ACQ is shown on the hand set display. If the couple of values is not consistent they were not saved and the display switches to a different indication: ACQ ABORTED #1 or #2.



Parameters in the HARDWARE SETTING menu from 1 (ID RMS MAX) to 21 (AUX SPEED #1) are safety relevant and only authorized technicians are admitted to change the default settings

13.3.7 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) SET TEMPERATURE

Factory adjusted.

2) HIGH ADDRESS

Zapi reserved

3) 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 13.3.3-14 and 13.3.3-15) in open loop application. It switches

- automatically to the default Level 15 after the self-acquisition.
- LEVEL 1: Used to manually set PULSE IN 180 DEG (see 12.5).
- LEVEL 2-10: Zapi reserved.
- LEVEL 11: Disables the alarms FB SENS LOCKED and MOTOR LOCKED till a new DEBUG OUTPUT hand setting.
- LEVEL 12: Not used
- LEVEL 13: Not used
- LEVEL 14: Disables the alarms FB SENS LOCKED and MOTOR LOCKED. It switches automatically to the default Level 15 recycling the key.
- LEVEL 15: Default value (no special functions activated).

4) CAN BUS SPEED

Set the baud rate on the can bus communication system.

5) 2ND SDO ID OFFS

Offset for an optional second index for the SDO frames. In case this adjustment is set to 0 (default value), Epsacw sends its SDO to its own index (main index defined in the Object Dictionary). In case two separated destinations are required for the SDO, the Epsacw already implements the possibility to send (sequenced) two distinct SDOs: the first will be send to the main index: the second will be send to an index given by the main index plus the offset specified by this adjustment.

6) AUX FUNCTION 11

This setting (level 0 to 5) specifies the toggle switches arrangement (one or two toggle switches and their succession inside a complete steered wheel revolution) (see also 12.4 AUX FUNCTION 11 manual setting).

- LEVEL 0: only one toggle switch in the straight ahead position. PROX SWITCH #1 (corresponding to CNA#12) is OFF when the STEER ANGLE is in the window 0 to 90 degrees.
- LEVEL 1: only one toggle switch in the straight ahead position. PROX SWITCH #1 (corresponding to CNA#12) is ON when the STEER ANGLE is in the window 0 to 90 degrees).
- LEVEL 2: two toggle switches in the straight ahead and 90 degrees position. PROX SWITCH #1 (corresponding to CNA#12) and PROX SWITCH #2 (corresponding to CNA#11) are both OFF when the STEER ANGLE is in the window 0 to 90 degrees).
- LEVEL 3: two toggle switches in the straight ahead and 90 degrees position. PROX SWITCH #1 (corresponding to CNA#12) is OFF and PROX SWITCH #2 (corresponding to CNA#11) is ON when the STEER ANGLE is in the window 0 to 90 degrees).
- LEVEL 4: two toggle switches in the straight ahead and 90 degrees position. PROX SWITCH #1 (corresponding to CNA#12) is ON and PROX SWITCH #2 (corresponding to CNA#11) is OFF when the STEER ANGLE is in the window 0 to 90 degrees).
- LEVEL 5: two toggle switches in the straight ahead and 90 degrees position. PROX SWITCH #1 (corresponding to CNA#12) and PROX SWITCH #2 (corresponding to CNA#11) are

both ON when the STEER ANGLE is in the window 0 to 90 degrees).

Depending by your arrangement, three couples of consistent settings are possible:

0 or 1 if you have one toggle switch.

2 or 5 if you have two concordant toggle switches.

3 or 4 if you have two discordant toggle switches.

By switching between the two values inside each couple, the steered wheel turns 180 degrees.

AUX FUNCTION 11 manual setting (see 12.4) deals about a simplified setting procedure.

7) SAFETY LEVEL

This adjustment applies a limitation to the SuC diagnosis. It has been foreseen for debug activity only.

When releasing on the field, LEVEL 4 is mandatory:

- LEVEL 0: SuC works only as a WD on the synch signal (only W.D. SYNCHRO alarm is enabled). MuC works even in case the SuC is not running.
- LEVEL 1: Alarms INPUT MISMATCH, SP MISMATCH, OUTPUT MISMATCH masked.
- LEVEL 2: Alarms SP MISMATCH and OUPUT MISMATCH masked.
- LEVEL 3: Alarm OUPUT MISMATCH masked.
- LEVEL 4: SuC Fully operational.



When releasing on the field, SAFETY LEVEL mut be set to LEVEL 4



Parameters in the SPECIAL ADJUSTMENTS menu are safety relevant and only authorized technicians are admitted to change the default settings

13.3.8 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 digits. Measurement of the stepper motor speed with sign in the range 0 to ± 5 Vdc.

2) FEEDBACK SECTOR

FEEDBACK SECTOR shows the current sector (i.e. configuration of the toggle switches within a steered wheel revolution). The steered wheel revolution is divided into 4 quadrants (sectors) corresponding to 4 different toggle switches configurations:

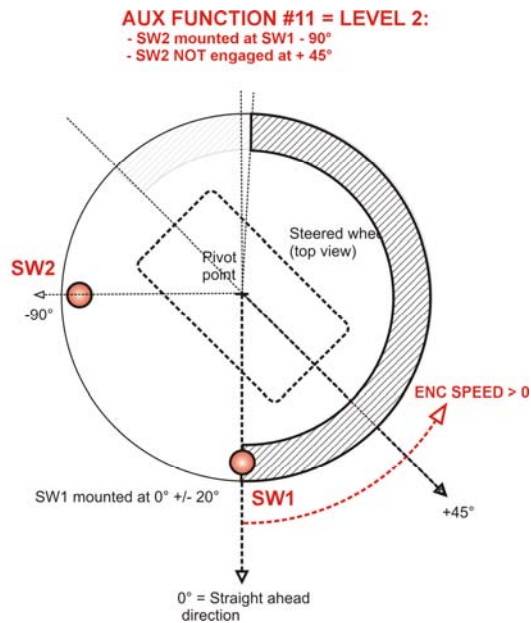


Figure 13.3.8-1

With two toggle switches (see figure 13.3.8-1).

The steered wheel is in the 1ST sector (FEEDBACK SECTOR is 1) when the configuration of the toggle switches is the one expected for a STEER ANGLE in the range 0 to +90 degrees.

The steered wheel is in the 2ST sector (FEEDBACK SECTOR is 2) when the configuration of the toggle switches is the one expected for a STEER ANGLE in the range +90 to +180 degrees.

The steered wheel is in the 3RD sector (FEEDBACK SECTOR is 3) when the configuration of the toggle switches is the one expected for a STEER ANGLE in the range -180 to -90 degrees.

The steered wheel is in the 4TH sector (FEEDBACK SECTOR is 4) when the configuration of the toggle switches is the one expected for a STEER ANGLE in the range -90 to 0 degrees.

With one toggle switch.

The steered wheel is in the 1ST sector (FEEDBACK SECTOR is 1) when the configuration of the toggle switch is the one expected for a STEER ANGLE in the range 0 to 180 degrees.

The steered wheel is in the 4TH sector (FEEDBACK SECTOR is 4) when the configuration of the toggle switch is the one expected for a STEER ANGLE in the range -180 to 0 degrees.

FEEDBACK SECTOR shows three readings in time sharing:

- 1st reading: Long duration reading (about 2secs): is the current sector. It can assume a value in the range 1.00 (1st sector), 2.00 (2nd sector), 3.00 (3rd sector) or 4.00 (4th sector).
- 2nd reading: Short duration reading (about 500msec): it is the inferior limit of the current sector (in degrees: STEER ANGLE is expected to be higher than this limit. POSITION ERROR alarm in case it isn't).
- 3rd reading: Short duration reading (about 500msec): it is the superior limit of the current sector (in degrees: STEER ANGLE is expected to be lower than this limit. POSITION ERROR

alarm in case it isn't).

FEEDBACK SECTOR does not change until a complete time sharing cycle (1st, 2nd and 3rd readings) has been represented on the display.

3) ENC COUNTING

Counts of the encoder vs. the real straight ahead direction (STEER ANGLE to 0 deg). At key-on when the straight ahead switch (SW1 to CNA#12) toggles, an offset (see STEER 0-POS DEG) corresponding to the displacement between straight ahead switch and actual straight ahead direction is written on the ENC COUNTING (i.e. ENC COUNTING in general is not null when the straight ahead switch toggles; ENC COUNTING is expected to be null when the truck is really driving in the straight ahead direction instead).

4) ENC SPEED

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

5) FREQUENCY

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

6) MOTOR VOLTAGE

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

7) MOTOR CURRENT

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

8) IQ RMS

Ampere value. Root Mean Square value of the quadrature current in the motor (torque component).

9) ID RMS

Ampere value. Root Mean Square value of the direct current in the motor (flux component).

10) TEMPERATURE

Degrees. Temperature of the controller base plate.

11) MOTOR TEMPERATURE

Degrees. Temperature of the motor windings measured with the thermal sensor inside the motor and connected to CNG#7.

12) PROX SWITCH #1

Provides real time the state of the CW toggle switch (connected to CNA#12). It is On (active) when CNA#12 is low.

13) PROX SWITCH #2

Provides real time the state of the CCW toggle switch (connected to CNA#11). It is On (active) when CNA#11 is low.

14) CW LIMIT LEVEL

When the maximum angle limitation via feedback sensors is enabled (see

option 90DEG LIMIT) and the STEER ANGLE overtakes the superior limit for the steered wheel angle limitation, the steered wheel angle will be limited and CW LIMIT LEVEL turns ON (active).

15) ACW LIMIT LEVEL

When the maximum angle limitation via feedback sensors is enabled (see option 90DEG LIMIT) and the STEER ANGLE 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).

16) I TFD

This is the real time measurement of the DC current in the load connected to CNA#10.

17) MOTOR POWER WATT

This is the real time measurement of the active power in Watts entering the motor.

18) STATUS #5

Reading STATUS #5 supports the embedded troubleshooting structure. It monitors the state of the voltage at the motor terminals at key-on when the three phase power bridge has not been turned on yet. STATUS #5 supplies two reading (see figure 14.3-1):

- 1st reading: Long duration reading (about 2secs): it is the voltage between motor terminals and battery rails before the three phase power bridge is been switched on.
- 2nd reading: Short duration reading (about 500msec): it is voltage between on the power rail capacitors (battery plus) and GND when the 1st reading has been collected.

1st reading provides a check-up feedback on the integrity of the insulation between motor terminals and battery rails before the three phase power bridge is driven.

19) STATUS#2

Reading STATUS #2 supports the embedded troubleshooting structure. It monitors the response of the steering system when entering the SELFCHCK #2 routine (see 13.3.6.22 SELFCHCK STATUS) consisting of turning the motor at a fixed speed of 25Hz. To run this selfchecking routine special adjustmenr SELFCHCK STATUS to LEVEL 2 and recycle the key. An alarm SELFCHCK #2 occurs and STATUS #2 in the TESTER menu collect the data (see 14.2). Selfcheck #2 provides a check-up response on the functionality of encoder and transmission (see 14.2)

20) STATUS#1

Reading STATUS #1 supports the embedded troubleshooting structure. It monitors the response of the steering system when entering the SELFCHCK #1 routine (see 13.3.6.22 SELFCHCK STATUS) consisting of injecting a fixed 14.7Adc current in the motor terminals. To run this selfchecking routine special adjustment SELFCHCK STATUS to LEVEL 1 and recycle the key. An alarm SELFCHCK #1 occurs and STATUS #1 in the TESTER menu collect the data (see 14.1). Selfcheck #1 provides a check-up response on the functionality of motor and power drives (see 14.1).

21) STEER ANGLE

This reading supplies the angle of the steered wheel in degrees with sign. This measurement is vs. the straight ahead orientation of the steered wheel (not vs the SW1 direction). This information is used for determining the sector inside the steered wheel revolution and it is used for properly set the AUX FUNCTION #11 (see 13.3.6.6) and for the diagnosis of the correspondence between sector and encoder measurement (POSITION ERROR alarm see 15.33).

22) DISPLAY ANGLE

This reading supplies the angle of the steered wheel in degrees with sign sent on the CAN Bus communication system. It is equal to the STEER ANGLE but with the sign given by option WHEEL DIRECTION. By changing WHEEL DIRECTION the sign sent on the CAN Bus (and collected by the display) will be reversed.

23) TRUCK SPEED

This reading supplies the traction speed in percentage of the MAX SPEED TRAC (see 13.3.5.12)

14 TROUBLESHOOTING

Below a Troubleshooting structure is composed with 5 status (readings of the TESTER menu) and 2 selfchecking routines to carry out on demand real time information of the state of the components of the system. In particular;

STATUS#1: selfcheck of the motor and power drives.

STATUS#2: selfcheck of the encoder and transmission.

STATUS#3: selfcheck available (NOT DONE).

STATUS#4: selfcheck available (NOT DONE).

STATUS#5: measure of the insulation between motor phases and battery.

14.1 STATUS #1: selfcheck of the Motor and of the Power Drives

Reading STATUS #1 carries out a voltametering measure of the the motor resistances between phase V and W (R_{vw}) and between phase W and U (R_{wu}) in milliohms. To run this selfchecking routine, enter the HARDWARE SETTING menu and set SELFCHK STATUS to LEVEL 1 and recycle the key. An alarm SELFCHK #1 occurs and a ID RMS MAX x SQRT(3/2) (i.e. $12 \cdot \text{SQRT}(3/2) = 14.7 \text{Adc}$ @ $V_{\text{batt}}=48\text{V}$) current will be injected in the motor and the motor resistances measured. STATUS #1 in the TESTER menu, shows real time four values in time sharing:

1ST VALUE: long duration value (about 2secs): it toggles between values 2 and 3. Value 2 means current injection involves terminals V and W. Value 3 means current injection involves terminals U and W.

2ND VALUE: first short duration value (about 500msec): this is the current injected from the 1st terminal and exiting from the 2nd terminal.

3RD VALUE: second short duration value (about 500msec): this is the current injected from the 2nd terminal and exiting from the 1st terminal.

4TH VALUE: third short duration value (about 500msecs): this is the motor resistance measured between 1st terminal and 2nd terminal

TROUBLESHOOTING with STATUS #1:

1ST VALUE is expected to toggle between 2 (injection between terminals V and W) and 3 (injection between terminals W and U)

2ND VALUE is expected to be 14 or 15 (amperes)

3RD VALUE is expected to be -14 or -15 (amperes)

4TH VALUE is expected in a window from 180 (milliohms) and 380 (milliohms)

(This is the resistance measured between two motor terminals and it changes a lot with the motor temperature). Readings of the motor terminal between V-W and W-U are expected to be close in between

Example of a correct sequence:

1. **1ST VALUE:** 2. Injection involves V and W.
2. **2ST VALUE:** 14 or 15 => [Adc] current from V to W.
Zapi DUT reports 14.
3. **3ST VALUE:** -14 or -15 => [Adc] current from W to V.
Zapi DUT reports -14.
4. **4ST VALUE:** 180 to 380 => [milliohms] resistance between V and W.
Zapi DUT reports 280.
5. **1ST VALUE:** 3. Injection involves W and U.

6. **2ST VALUE:** 14 or 15 => [Adc] current from W to U.
Zapi DUT reports 15.
7. **3ST VALUE:** -14 or -15 => [Adc] current from U to W.
Zapi DUT reports -14.
8. **4ST VALUE:** 180 to 380 => [milliohms] resistance between W and U.
Zapi DUT reports 290.

Alarm **SELFCHECK #1** after a while turns to:

CHECK #1 OK: occurs when the system passes the SELFCHECK #1. To pass SELFCHECK #1 following conditions must be matched (AND logic):

Current from V to W to 14 or 15

AND

Current from W to V to -14 or -15

AND

Current from W to U to 14 or 15

AND

Current from U to W to -14 or -15

AND

Motor Resistance V to W in the window 180 to 380

AND

Motor Resistance W to U in the window 180 to 380

SELCK 1.1 VBATT: occurs in case the rail voltage (battery voltage) is lower than 29V (for 48V battery) and 19V (for 24V battery). It reports a failure on the cable between plus or minus battery and the controller.

SELCK 1.2 MOT VW: occurs in case the linked voltages between terminal V and W (Vvw and Vwv) to get the expected current (14.7Adc) are both higher than 10Vdc. It reports a failure with terminal W or terminal V of the motor (interrupted).

SELCK 1.3 MOT WU: occurs in case the linked voltages between terminal W and U (Vwu and Vuw) to get the expected current (14.7Adc) are both higher than 10Vdc. It reports a failure with terminal U or terminal W of the motor (interrupted).

SELCK 1.4 CTL VW: occurs in case only one between the linked voltages at terminals V and W (Vvw or Vwv) to get the expected current (14.7Adc) is higher than 10Vdc. It reports a failure in a power mosfet in the half bridges of terminals V or W.

SELCK 1.5 CTL WU: occurs in case only one between the linked voltages at terminals W and U (Vwu or Vuw) to get the expected current (14.7Adc) is higher than 10Vdc. It reports a failure in a power mosfet in the half bridges of terminals W or U.

SELCK 1.6 CTL KO: occurs in case none of the above failures has been detected but at least one between the injected currents (Ivw, Iwv, Iwu, Iuw) is lower than 10Adc (when 14.7Adc are expected instead). It reports a generic failure in the controller (power or logic).

SELCK 1.7 STA #1: occurs in case none of the above conditions has been detected. So reading and deepen analysis of STATUS#1 information is needed for deciding the proceeding.

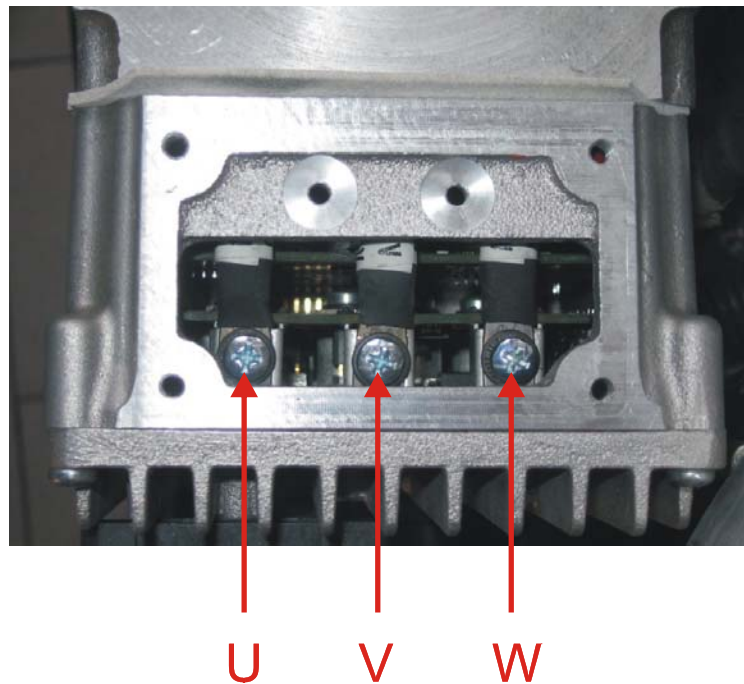


Figure 14.1–1

14.2 STATUS #2: selfcheck of the Encoder and Transmission

Reading STATUS #2 in the tester menu monitors the response of the steering system when commanded to rotate at a fixed speed of 25Hz. To run this selfchecking routine set option SELFCHK STATUS to LEVEL 2 and recycle the key. An alarm SELFCHECK #2 occurs and STATUS #2 in the TESTER menu, shows real time four values in time sharing:

1ST VALUE: long duration value (about 2secs): this is the average value of the current (Aac) in the motor when commanded to turn at a fixed speed (25Hz). (If the steered wheel is lifted up the expected value is about 3.5Aac @ 25°).

2ND VALUE: first short duration value (about 500msecs): it is the minimum value (valley detection) of the encoder pulses counted in 16msec during this selfchecking routine @ fixed speed (25Hz).

3RD VALUE: second short duration value (about 500msecs): it is the average value of the encoder pulses counted in 16msec during this selfchecking routine @ fixed speed (25Hz). (Expected value is 6.42 pulses per 16msec).

4TH VALUE: third short duration value (about 500msecs): it is the maximum value (peak detection) of the encoder pulses counted in 16msec during this selfchecking routine @ fixed speed (25Hz).

2ND and 4RD values are expected to be integer values, a little bit lower (2ND) and a little bit higher (4TH) than 3RD value. For instance, 2ND value could be 5.00 and 4TH value could be 7.00 (pulses per 16msec).

So, if you launch the STATUS #2 closed loop selfchecking routine with a steered wheel lifted up, following data collection is an example of the correct sequence:

1. **1ST VALUE:** lower than 6.50 [Aac].
Zapi DUT reports 3.6 [Aac].

2. **2ST VALUE:** 4.00 [minimum counting within 16msec].
Zapi DUT reports 5.00 [events per 16msec].
3. **3ST VALUE:** 6.42 [averaging counting within 16msec].
Zapi DUT reports 6.41 [events per 16msec].
4. **4ST VALUE:** 8.00 [maximum counting within 16msec].
Zapi DUT reports 7.00 [events per 16msec].

In case the values detected are different from the above, a fault occurred.

TROUBLESHOOTING with STATUS #2:

Alarm **SELF CHECK #2** after a while turns to:

CHECK #2 OK: occurs when the system passes the SELF CHECK #2. To pass SELF CHECK #2 following conditions must be matched (AND logic):

1ST value (current) lower than 6.5Adc

AND

2ND value (minimum pulses in 16msec) higher equal than 4

AND

3RD value (maximum pulses in 16msec) lower equal than 8

SELCK 2.1 VBATT: occurs in case the rail voltage (battery voltage) is lower than 29V (for 48V battery) and 19V (for 24V battery). It reports a failure on the cable between plus or minus battery and the controller.

SELCK 2.2 ENC LO: occurs in case the 2ND value (minimum pulses in 16 msec) has been detected (valley detection) lower than 2 and the 1ST value (current in the motor) has been detected lower than 20Aac. It reports a temporary valley in the encoder counting. Reason could be a noise in the encoder, a bad encoder connection.

SELCK 2.3 ENC HI: occurs in case the 4TH value (maximum pulses in 16 msec) has been detected (peak detection) higher than 8 and the 1ST value (current in the motor) has been detected lower than 20Aac. It is a not likely condition and reports a temporary peak in the encoder counting. Reason could be a noise in the encoder, two channels of the encode toggles in the same time (no 90 degrees shift) a bad encoder connection.

SELCK 2.4 IMAX: occurs in case the 1ST value (current in the motor) has been detected higher than 40A and the 3RD value (average pulses in 16msec) has been detected lower than 4. It means the system is not able to reach the commanded speed (25Hz). Two possibilities:

a) the steered wheel MOVES SLOWLY and the 2ND value (minimum pulses in 16msec) is less equal than 0 and the 3RD value (average pulses in 16msec) is less than 1.00. Then the encoder is failed

b) the steered wheel DO NOT MOVE (locked). The problem is too friction likely in the transmission. Less probable in the motor (e.g. mechanical problem on a ball bearing)

SELCK 2.5 I > 20A: occurs in case the 1ST value (current in the motor is higher than 20Aac) and the 3RD value (average pulses in 16msec) is higher than 6pulses (required speed 25Hz reached). It reports a situation of high friction to steer. A test with the steered wheel lifted up can confirm the high friction is generated inside the system (e.g. a failure in a ball bearing) not for an external condition like hard floor or wheel overloaded.

SELCK 2.6 I > 10A: occurs in case the 1ST value (current in the motor is higher than 10Aac) and the 3RD value (average pulses in 16msec) is higher than 6pulses (required speed 25Hz reached). Higher than 10Aac are expected in case the steered wheel is on the floor in no load and no travel condition. Then about 12Aac has been measured on a DUT on a smooth surface. In case THE STEERED WHEEL IS LIFTED UP, it reports a situation that could be of high friction. When the steered wheel is lifted up, lower than 6.5Aac are expected. Anyway, even for a

listed up truck, this is not a real problem but a warning that some aging (e.g. grease in the transmission) or singular condition (e.g. very low temperature grease) or some wear has occurred in the system.

SELCK 2.7 POWER: occurs in case the actual current in the motor is detected lower than the commanded motor current required to reach 25Hz speed. It reports a problem in the power actuator of the system (including 3phase power bridge and motor). A SELFCHECK #1 may help to clarify whether the problem is in the motor or in the controller.

SELCK 2.8 STA #2: occurs in case none of the above conditions has been detected. So reading and deepen analysis of STATUS#2 information is needed for deciding the proceeding.

Below is a list of cases leading to this SELCK 2.8 STA #2 instance.

1. STATUS #2 reports 2ND value (motor current) in the admitted range (14 or 15), 3RD value (motor current) in the admitted range (-14 or -15) but the 4TH value (motor resistance) lower than 180 milliohms. This situation reports to a probable short circuit between two motor terminals

ALARMS recalling STATUS #2

1) FB SENSOR LOCKED

Alarm 0xFFFF1 Group #0:

14.3 STATUS #5: measure of the insulation of the motor and battery

Reading STATUS #5 in the tester menu monitors the state of the voltage at the motor terminals at key on when the three phase power bridge is still switched off (see Figure 14.3-1 below). Three bias resistances (4.5K each give a total impedance is about 1.5Kohms) keep the voltage at the motor terminal to about 13V. In case the motor or the controller has a leakage current to battery minus or battery plus, a lower or higher voltage can be found. This situation probably reports to a failure either in the three half bridges power drives or in the motor. It shows real time two values in time sharing:

1ST VALUE: long duration value (about 2secs): this is the bias voltage measured at the motor terminals when the three phase power bridge is switched off. It is frozen to the sample detected when either the diagnosis passed or when the alarm occurs (INIT VMN NOT OK or CAPACITOR CHARGE alarms).

2ND VALUE: first short duration value (about 500msecs): it is the voltage at the rail capacitors when the 1ST VALUE has been picked on.

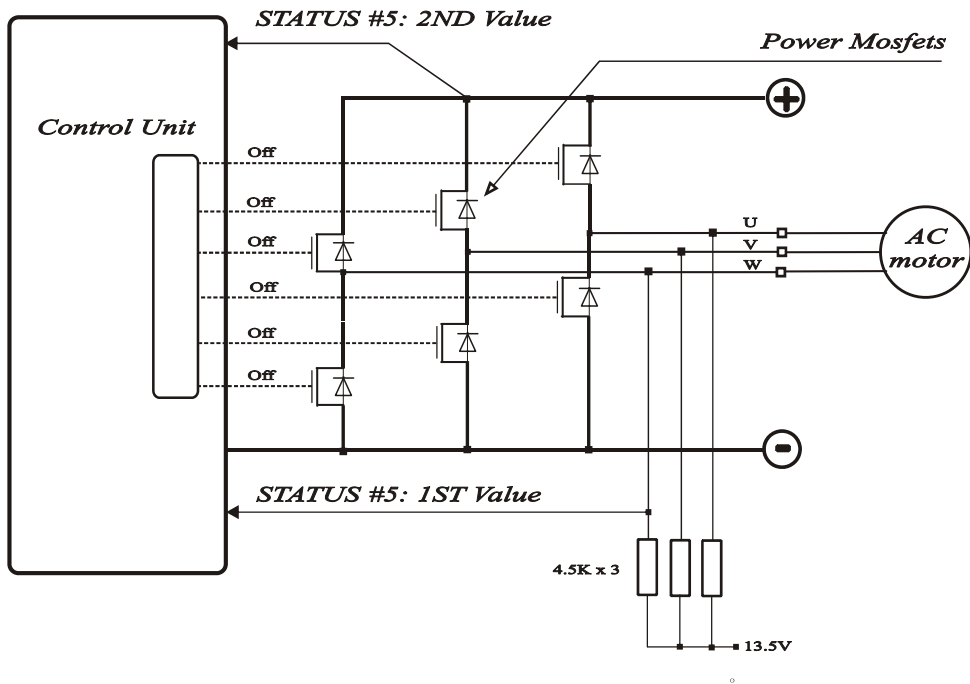


Figure 14.3-1

ALARMS recalling STATUS #5:

- 1) **INIT VMN NOT OK**
Alarm 0xFFFB Group #0:
- 2) **CAPACITOR CHARGE**
Alarm 0xFF3C Group #0:

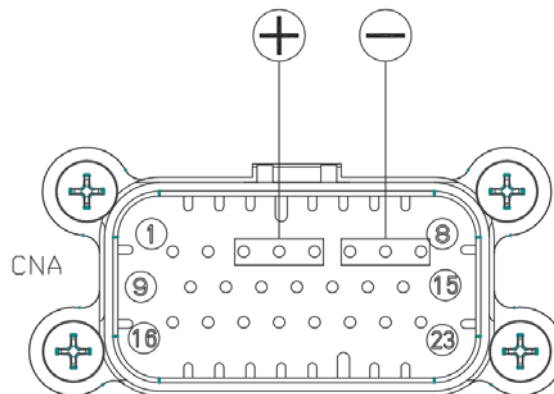


Figure 14.3-2

15 EPSACW ALARMS

The list of the alarms occurring in the epsacW is listed in 15.2. When an alarm occurs, traction must be brought to a controlled safe state. This activity IS FULLY IN CHARGE OF THE LIFTTRUCK MANUFACTURER. Refer to 15.1 for the details.

15.1 Stop Traction when epsacW is no longer operative

In case of an alarm in the epsacW, the traction must be brought to a controlled safe state (traction stop or traction speed limitation). The epsacW invokes this event with a STOP TRACTION REQUEST sent on the CAN Bus communication system. An optional hardwired output (CNA#14) is available too (optional and activated only on a customer's demand).



Whenever at least one of the two microcontrollers in the epsacW detects an alarm in the steering system, that microcontroller turns on (from LOW to HIGH) a STOP TRACTION REQUEST bit in a PDO (STATUS WORD) continuously sent to the unit designated to stop the traction. The job in the Zapi steering system finishes when the STOP TRACTION REQUEST has been sent. So the Lifttruck Manufacturer is responsible for coordinating the communication between different units in the truck and furthermore for testing and validating that this alarm information will be properly handled in the destination unit and leading to a traction safe state when the steering system is no longer operative.

Let us call the unit in the truck designated to lead the traction in a safe state (whatever it is) as the Traction Master Control (TMC). TMC is expected to continuously send a PDO (used as a synchronization frame) to the epsacW:.

TMC -> EPS_MuC_SuC (synch like frame)

The two uCs inside the epsacW must answer.

- 1) EPS_MuC - > TMC
- AND
- 2) EPS_SuC - > TMC

These response PDOs includes the STOP TRACTION REQUEST bit.
The time repetition for this (synch) PDO TMC -> EPS_MuC_SuC MUST BE LOWER EQUAL THAN 32msec.

TMC - > EPS_MuC_SuC: Every Tr <= 32msec
EPS_MuC - > TMC: MuC STOP TRACTION REQUEST
EPS_SuC - > TMC: SuC STOP TRACTION REQUEST

The job in the Zapi steering system finishes when the STOP TRACTION REQUEST has been sent to the TMC. The position of the STOP TRACTION REQUEST flag is given by table 15.1-1 below:

Zapi P/N	TCM->EPS ID.Byte.Bit	EPS_MuC -> TCM STOP TRACTION REQ ID.Byte.Bit	EPS_SuC ->TCM STOP TRACTION REQ ID.Byte.Bit	Expected Time repetition: (*)
F07198-ZP	218.X.X	198.0.3	199.0.3	every TCM-> EPS (T=32msec)

Table 15.1-1

(*) In case the synch PDO TMC->EPS is lacking longer than 100msec, epsacW sends its response PDOs to the TMC every 100msecs with STOP TRACTION REQ turned TRUE (Alarm CAN BUS KO).

Together with the STOP TRACTION REQUEST the epsacW sends also an EMERGENCY or a PDO with the indication of the alarm code. **BUT THIS IS ONLY an information aside; it is mandatory that the traction shall be stopped following the event STOP TRACTION REQUEST turned TRUE.**

15.2 EPSACW ALARMS LIST

Below the alarms list for the epsacW is supplied.

Listed Alarms are organized in four groups:

Group #0: steering motor is immediately shut off (null holding torque).

Group #1: steering motor is supplied with a DC current (ID RMS MAX) 5 sec long.

Group #2: steering motor is braked to a null speed 5sec long.

Group #3: steering motor is kept in full control 5sec long.

In case an alarm occurs, we assume the truck gets stopped within 5secs and so, when possible, we keep the steering system operative up to 5secs (traction is immediately DEMANDED TO STOP instead).

In the list below:

Node #18 (CAN Consolle) and #6 (remote Zapi hand-set) is the Master Microcontroller (MuC)

Node #19 (CAN Consolle) and #38 (remote Zapi hand set) is the Slave Microcontroller (supervisor-SuC).

Letters inside square brackets refers to the Master and Slave nodes.

Master microcontroller and Slave microcontroller reply the same tests on the system for mostly of the alarms below; when the alarm is raised by only one of them, only one Node is listed in square brackets.

There are two alarm codes: hexadecimal and decimal. The decimal number is sent on the Can bus and collected by the display. Hexadecimal is the Can Open Alarm Code (not active).

1) FB SENSOR LOCKED

Alarm 0xFFF1=241 Group #2 [M,S]:

- Cause: This is a closed loop monitoring. This alarm occurs if the actual speed (freq_enci in Figure #7.1-1 measured with the main encoder) does not pursue the commanded speed (set point) (freq_req in Figure #7.1-1 coming from a pre-elaboration of the stepper motor outputs) longer than 500msec @ traction speed higher than 15% (at lower traction speed, time delay increases up to 2.5secs when traction speed is lower than 5%). If the displacement between commanded and actual speed stays higher than 30% of the commanded speed and higher than

5Hz longer than a time delay of 500msec (changing vs. truck speed), this alarm occurs. Monitoring is suspended 400ms long every time the sign of the error (freq_req_freq_enc.) changes from pos to neg or viceversa.

- Remedy: This alarm can be due to:
 1. At least one encoder channel broken
 2. Too much friction in the transmission/gears
 3. A failure in the power controller
 4. A failure in the motor (e.g. an encoder locked or a motor phase broken).

2) MOTOR LOCKED

Alarm 0xFFDC=220 Group #0 [M,S]:

- Cause: This alarm occurs when the current in the motor stays higher than 90% I_{max} longer than 1 secs when the traction speed is higher than 15% (delay becomes 5 secs when the traction speed is lower than 5%).
- Remedy: Too much torque required to steer or problem in the encoder (launch selfcheck #2).

3) HIGH CURRENT

Alarm 0xFF46=70 Group #0 [M,S]:

- Cause: This alarm occurs at key on, in case the circuit for limiting the max current via Hardware is always active (can be due to a failure of a current amplifier).
- Remedy: If it is repetitive, it is necessary to replace the controller

4) POWER FAILURE #1

Alarm 0xFF49=73 Group #2 [M,S]:

- Cause: This alarm is raised by the MuC when the current in phase U of the motor lower than 5.4Arms 100msec long even if it is commanded higher than 28% I_{max}.
This alarm is raised by the SuC in case the I_{2t} of the current in the battery overtakes the admitted limit of 22000A²s (i.e. overload protection of the battery connections).
- Remedy: MuC: if it is repetitive, check if the battery is connected to the controller. Otherwise the problem can be a failure in the power three phase bridge or in terminal U motor connection.
SuC: an overload is occurred in the steering controller. One possibility is too much friction in the transmission. Launch selfcheck #2 with the steered wheel lifted up (and then on the floor) to measure the current in the motor when turning the steered axle. Check the diagnostic response (STATUS#2 and alarm message).

5) POWER FAILURE #2

Alarm 0xFF48=72 Group #2 [M]:

- Cause: Current in phase V of the motor lower than 5.4Arms 100msec long even if it is commanded higher than 28% I_{max}.
- Remedy: If it is repetitive, check if the battery is connected to the controller. Otherwise the problem can be a failure in the power three phase bridge or in terminal V motor connection.

6) POWER FAILURE #3

Alarm 0xFF47=71 Group #2 [M]:

- Cause: Current in phase W of the motor lower than 5.4Arms 100msec long even if it is commanded higher than 28% I_{max}.
- Remedy: If it is repetitive, check if the battery is connected to the controller. Otherwise the problem can be a failure in the power three phase bridge or in terminal W motor connection.

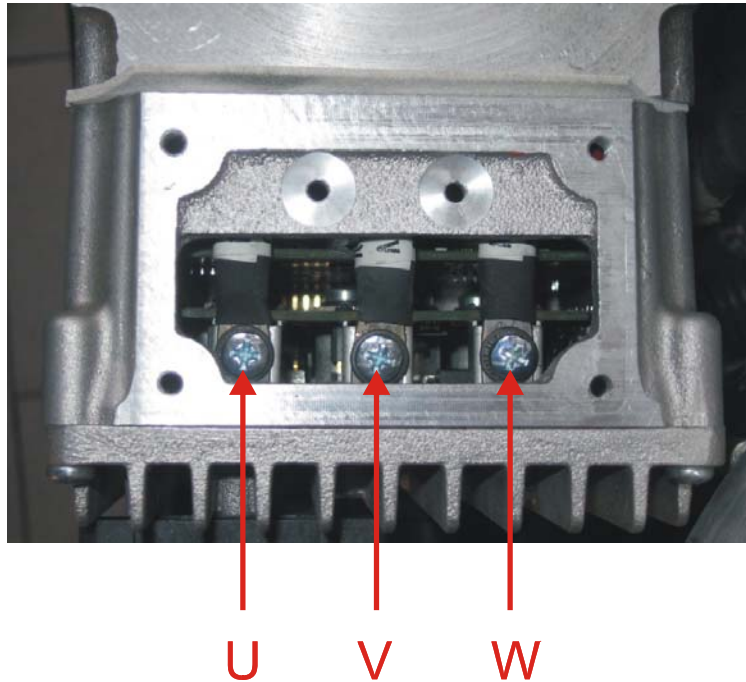


Figure 15.6-1

7) D LINE SENSOR KO

Alarm 0xFFF3=243 Group #2 [M,S]:

- Cause: This alarm occurs when the mean voltage on the Direct line of the stepper motor (connection CNA#20) 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#20 and the minus battery (with the stepper motor at rest) is expected being very low (close to 30 ohms).

8) Q LINE SENSOR KO

Alarm 0xFFF2=242 Group #2 [M,S]:

- Cause: This alarm occurs when the mean voltage on the Quadrature line of the stepper motor (connection CNA#17) 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#17 and the minus battery (with the stepper motor at rest) is expected being very low (close to 30 ohms).

9) HIGH TEMPERATURE

Alarm 0xFF3D=61 Group #3 [M]:

- Cause: This alarm occurs when the temperature in the cases of the power mosfets is:
 - a) higher than 80 degrees longer than 3.84secs @ MAXIMUM CURRENT=70A
 - OR
 - b) higher than 90 degrees longer than 3.84secs @ MAXIMUM CURRENT=50A.
- Remedy: Improve the cooling of the controller; otherwise it is necessary to replace the controller.

10) MOTOR TEMPERAT.

Alarm 0xFF41=65 Group #3 [M,S]:

- Cause: This alarm occurs only when DIAG MOTOR TEMP is ON and the thermal sensor inside the motor measures a temperature higher than 120 degrees. It occurs also when the motor resistance has been acquired with a temperature in the motor higher than 120 degrees (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.

11) STBY I HIGH

Alarm 0xFF35=53 Group #0 [M,S]:

- Cause: This alarm occurs two ways:
 1. at key-on, in case at least one current amplifier on phases U and W is not in a narrow window of +/- 300mV around 2.5Vdc 50msec long (sampling time 10msec for 5 consecutive samples). (Admitted outputs of the current amplifiers at key on are from 2.2V to 2.8V).
When the diagnosis has been passed, the offset of the current amplifiers (IU_zero and IW_zero) will be acquired.
 2. with steer at rest, in case at least one current amplifier on phases U and W is not in a narrow window of +/- 150mV around IU_zero or IW_zero 96msec long (sampling time 8msec for 12 consecutive samples).
- Remedy: If it is repetitive, it is necessary to replace the controller

12) VMN NOT OK

Alarm 0xFF20=32 Group #0 [M,S]:

- Cause: This alarm occurs at key on, in case at least one voltage amplifiers on linked voltage Vv-Vu and Vu-Vw is not in a narrow window of +/- 300mV around 2.4Vdc 50msec long (sampling time 10msec for 5 consecutive samples). (Admitted outputs at rest are from 2.1V to 2.7V).
When the diagnosis has been passed, the offset of the voltage amplifiers (Vvu_zero and Vuw_zero) will be acquired.
- Remedy: If it is repetitive, it is necessary to replace the controller

13) LOGIC FAILURE #3

Alarm 0xFF11=17 Group #0 [M,S]:

- Cause: This alarm occurs with steer at rest in case the amplifier on the linked voltage Vv-Vu is not in a narrow window of +/- 250mV around Vvu_zero 96msec long (sampling time 8msec for 12 consecutive samples).

- Remedy: It is necessary to replace the controller.

14) LOGIC FAILURE #4

Alarm 0xFF10=16 Group #0 [M,S]:

- Cause: This alarm occurs with steer at rest in case the amplifier on the linked voltage Vu-Vw is not in a narrow window of +/- 250mV around Vuw_zero 96msec long (sampling time 8msec for 12 consecutive samples).
- Remedy: It is necessary to replace the controller.

15) DATA ACQUISITION

Warning 0xFFF5=245 with eps off and no drive [M]:

- Cause: This alarm occurs during max current regulation (factory adjusted) and when a procedure to acquire the motor resistance is launched. The acquisition of the motor resistance is not implemented yet.
- Remedy: Recycle the key

16) EEPROM KO

Alarm 0xFF0D=13 Group #0 [M,S]:

- Cause: Every microcontroller has its own Eeprom with two parameters lists (to have a local back up copy). Each list has its own checksum. When both checksums are wrong, this alarm occurs. In case a parameter list has a wrong checksum it will be repaired using the second list (back up copy with a correct checksum).
- Remedy: Make a Clear Eeprom. If the problem persists replace controller.

17) PARAM TRANSFER

Alarm 0xFFF4=244 Group #0 [M]:

- Cause: Master uC and Slave uC has its own parameter list (with its local back up copy). Change of a parameter is handled by the MuC only. MuC writes its own parameter and commands the SuC to do the same for its parameter list. Execution of the write command in the SuC is protected by a password. This alarm is raised up by the MuC in case SuC refuses to do the write command.
- Remedy: Try to change one more time a parameter. If the problem persists replace controller.

18) ANALOG

Alarm 0xFFFD=253 Group #0 [M,S]:

- Cause: This alarm occurs two ways:
 1. At key-on, the A/D converter is turned on and it is expected to complete a first conversion of the analog inputs within 16msec. In case it isn't, this alarm occurs.
 2. In steady state conditions, the main signals (motor currents and sensor at the steering wheel) are demanded for a new A/D conversion every 250usec. In case no new conversion is successfully ended within 1.25msec this alarm occurs (i.e. 5 consecutive conversions failed).
- Remedy: Recycle the key. If problem persists replace the controller.

19) M/S PAR CHK MISM

Alarm 0xFFDD=221 Group #0 [M]:

- Cause: MuC compares its checksum for the parameters list with the checksum of the parameters list in the SuC. In case they are mismatched, MuC raises this alarm.
- Remedy: Check which parameter(s) is different between MuC and SuC and update (write) the unmatched parameter(s). To easily fix the problem make a Clear Eeprom.

20) MAIN CONT. OPEN.

Warning 0xFF30=48 with eps off and no drive [M,S]:

- Cause: This warning is active when the steering controller is receiving via Can bus the information that the power line contactor is open.
- Remedy: This is not a problem in the Eps. When this warning is raised up it means the line contactor is open (or not closed yet).

21) INPUT MISMATCH YY

Alarm 0xFFFA=250 Group #0 [S]:

- Cause: MuC and SuC read the inputs independently each other. SuC takes care the values that it is reading are matched real time with the values the MuC is reading. This alarm occurs in case it isn't. SuC specifies which input led to a mismatch with a hex code (see above YY pair).
Inputs failed between MuC and SuC can be:
 1. Mismatch on straight ahead or 90 degrees switch level (SW1 on CNA#12 and SW2 on CNA#11)
YY = 83h
 2. Mismatch in the quadrant of the MDU in the 360 degrees revolution (SW1 vs. SW2 vs. AUX FUNCTION #11 setting).
YY=08h
 3. Mismatch in the Stepper Motor speed larger than max_stepper_motor_speed/5 (CNA#20 and CNA#17).
YY=04h
 4. Mismatch in the Encoder counting larger than 10 counts (a 2296 counting corresponds to 180 MDU degrees) (CNG#1 and CNG#3).
YY=20h
- Remedy: If it is repetitive, it reports a problem in the controller.

22) SP MISMATCH YY

Alarm 0xFFCF=207 Group #0 [S]:

- Cause: According the command, MuC and SuC calculate independently each other the speed set point for the steering motor. SuC takes care the values that it is calculating is matched real time with the values the MuC is calculating. This alarm occurs in case it isn't. SuC specifies which condition led to a mismatch with a hex code (see above YY pair).
Conditions failed between MuC and SuC can be:
 1. When NOT in closed loop max angle limitation, a mismatch on the steering motor speed set point larger than 10Hz.
YY = 01h.
 2. When in closed loop max angle limitation, a mismatch consisting of MuC has detected the condition for the max angle limitation and the SuC has not (or viceversa).
YY = 02h
 3. When in closed loop for a recovery at rest, a mismatch

consisting of MuC has detected the condition for a recovery at rest condition and the SuC has not (or viceversa).
YY = 04h

- Remedy: If it is repetitive, it reports a problem in the controller.

23) OUTPUT MISMATCH YY

Alarm 0xFFD0=208 Group #0 [S]:

- Cause: MuC and SuC read the commands and calculate the steering motor set point independently each other. Then MuC actuates the motor; SuC checks real time the action on the motor is complying with the steering motor set point. This alarm occurs in case it isn't. SuC specifies which condition led to a mismatch with a hex code (see above YY pair).

Conditions failed between MuC and SuC can be:

1. Actual and commanded (set point) steering motor speeds have a displacement larger than 10Hz and opposite sign.
YY = 03h.
2. Actual and commanded (set point) steering motor speeds have the same sign, displacement larger than 10Hz but the actual speed is lower than 50% of the commanded speed.
YY = 05h
3. At least one between mismatches 1. and 2. is concurring. Then actual and commanded (set point) torque currents have a displacement larger 3Aac and opposite sign.
YY = 0Bh when 1. is concurring; 0Dh when 2. is concurring
4. At least one between mismatches 1. and 2. is concurring. Then actual and commanded (set point) torque currents have the same sign, displacement larger than 3Aac but the actual torque current is lower than 50% of the commanded torque current.
YY = 13h when 1. is concurring; 15h when 2. is concurring.

- Remedy: If it is repetitive, it reports a problem in the controller.

24) WAITING MASTER

Warning 0xFFED=237 with eps off and no drive [S]:

- Cause: At key on, SuC expects the MuC sends a "ready to steer" frame on the local CAN Bus communication system. In case it lacks longer than 4secs this warning occurs.
- Remedy: If it is repetitive, it reports a problem in the controller.

25) WRONG SLAVE VER

Alarm 0xFFD2=210 Group #0 [M]:

- Cause: This alarm is raised by MuC in case the Software release in MuC and SuC are not matched (different release).
- Remedy: Download the same software release (same number) on both microcontrollers.

26) STEER HAZARD

Warning with eps on 0xFF55=85 [M]:

- Cause: This warning occurs when the steered wheel reaches the maximum angle.
- Remedy: turns the steering wheel in the opposite direction.

27) BAD STEER 0-SET

Warning with eps on 0xFF51=81 [M,S]:

- Cause: This warning occurs when Hardware Setting 0-POS TEACHING has been turned ON (and the key recycled).
- Remedy: Turn off the key.

28) SLAVE ALARM XX

Warning with eps off 0xFFED=237 [M]:

- Cause: When SuC raises an alarm it cuts off the power stage and steering motor cannot be actuated anymore. Then MuC raises this warning. In the Zapi console, MuC specifies the LSByte of the SuC alarm code on the XX position. For instances:
 1. LOGIC FAILURE #4: SLAVE ALARM 10
 2. OUTPUT MISMATCH: SLAVE ALARM D0
 3. INPUT MISMATCH: SLAVE ALARM FA
 4. SP MISMATCH: SLAVE ALARM CF
- Remedy: If it is repetitive, it reports a problem in the controller.

29) CAN BUS KO

Alarm 0xFFFF7 Group #3=247 [M,S]:

- Cause: Both MuC and SuC lack of the Traction Can Bus messages (Can ID 0x388 for MuC and 0x389 for SuC) longer than 200msec, this alarm occurs.
- Remedy: Problem can be in a wrong Can Bus connection, traction controller switched off or not mounted. Identification of the root of the problem needs a Can Bus analyzer.

30) EPS NOT ALIGNED

Warning 0xFFEE=238 with eps on and no drive [M,S]:

- Cause: This warning occurs at key on in three ways:
 1. No edge on the straight ahead switch (SW1 on CNA#12) longer than 3secs
OR
 2. No edge on the straight ahead switch (SW1 on CNA#12) within 180 degrees rotation of the MDU
OR
 3. The encoder is not able to return to the 0 degrees position (straight ahead) after the edge on SW1 has been detected.
- Remedy: STATUS #2 Selfchecking routine helps to found the root of the problem. This

31) INIT VMN NOT OK

Alarm 0xFFFFB=251 Group #0 [M]:

- Cause: After key-on, with the three phase power bridge off, the DC bus voltage is expected to raises up to 14Vdc within 3.2secs (alarm CAPACITOR CHARGE below if it isn't). In the same time, steering controller monitors the common voltage at the motor terminals (see STATUS #5 1ST value in Fig 15.31-1) and raises this alarm when the 3.2secs time-out is expired and:
 - a) the common voltage is lower than 7Vdc (bottom power mosfet shortcircuited to -B).
OR
 - b) the common voltage is stuck to the DC Bus (top power mosfet shorcircuited to +B). (It is considered stuck in case it is in a window of +/- 1Vdc around the DC Bus).
 STATUS #5 in the TESTER menu, supplies the real time value

- Remedy: of this common voltage on its long duration instance. Try to disconnect all the motor terminals from the controller, recycle the key and read STATUS #5. If the long duration instance (i.e. 1ST value) is in a window 8 to 13.5Vdc, the problem is a dispersion (lost of insulation of the motor). Otherwise replace the controller.

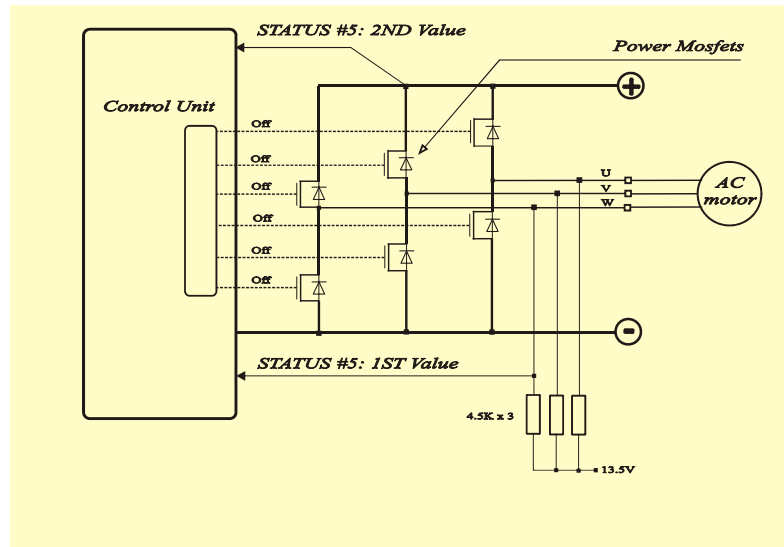


Figure 15.31-1

32) CAPACITOR CHARGE

Alarm 0xFF3C=60 Group #0 [M]:

- Cause: This alarm occurs at key on in case the DC Bus (rail capacitors) doesn't reach a minimum value of 14Vdc within 3.2secs despite it is expected to do. STATUS #5 supplies the real time value of the battery link (+B) in its short duration instance (2ND value in Fig. 15.31-1).
- Remedy: Some cases:
 - a) if this alarm is only reported in the steering controller, check the continuity of cables to CNA#3-4-5 from battery source and eps.
 - b) if the cables to CNA #3-4-5 are OK, measure the voltage between CNA#3-4-5 and -B within 3 sec after key-on. Only in case the voltage measured is higher than 14Vdc (and short duration instance on STATUS#5 is lower instead) replace the controller.
 - c) In case the voltage measured between CNA#3-4-5 and -B is close to 0 there are two possibilities:
 1. Short circuit on the DC rail and -B inside the eps (disconnect CNA#3-4-5 and measure the voltage in the traction controller DC bus (+B to -B posts): replace eps in case DC bus voltage of the traction controller raises up to higher than 14Vdc.
 2. Short circuit on the DC rail and -B on another unit in the truck.

33) POSITION ERROR

Alarm 0xFFE4=228 Group #2 [M]:

- Cause: This alarm occurs for an error in the redundant test of the

feedback sensors. Here we have an encoder and one (two) toggle switches.

This alarm occurs whether the sector (toggle switches configuration) and the encoder counting are not matched. The sector is provided with the FEEDBACK SECTOR reading in the tester menu (see 13.3.8.2); the encoder counting is provided with the STEER ANGLE reading in the tester menu.

In case of two toggle switches:

STEER ANGLE [degrees]	Admitted FEEDBACK SECTOR
-15 to +15	1 st or 4 th
+15 to +75	1 st
+75 to +105	1 st or 2 nd
+105 to +165	2 nd
+165 to -165	2 nd or 3 rd
-165 to -105	3 rd
-105 to -75	3 rd or 4 th
-75 to -15	4 th

In case of one toggle switch:

STEER ANGLE [degrees]	Admitted FEEDBACK SECTOR
+15 to +165	1 st
-165 to -15	4 th

When the FEEDBACK SECTOR and STEER ANGLE don't meet the above correspondence, an alarm POSITION ERROR occurs in less than 100msec.

NOTE: The thresholds of the STEER ANGLE admitted for every FEEDBACK SECTOR reported in the above tables, refers to an ideal case with STEER 0-POS DEG set to 0 degrees (no offset between SW1 and null angle) and a cam 180 degrees long. The real thresholds affected by SW1 offset and cam length are shown real time on the FEEDBACK SECTOR reading.

- Remedy:

If the alarm occurs when installing a new controller, be sure the AUX FUNCTION 11 corresponds to the toggle switches arrangement you have (see 12.3 and 12.4) and PULSE IN 180 DEG. was correctly set (see 12.5 and 12.6).

If the alarm occurs after the set-up was correctly performed, search for a failure on a toggle switch or on the encoder.

The troubleshooting consists of comparing STEER ANGLE and FEEDBACK SECTOR when this alarm occurs. In case of an alarm, they are expected to infringe the admitted correspondences of the above tables. Then the problem could be in a sensor (check PROX SWITCH 1 and PROX SWITCH 2) or in the encoder (check STEER ANGLE and FEEDBACK SECTOR).

A list of possible failures mode follows:

1. A switch changes its level despite it is not engaged by the iron plate (cam) on the steered wheel.
2. If the encoder consists of a sensor bearing, a ring of the sensor bearing has 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.
- 3. Fault in the low resolution encoder (like magnet loosened or a hall sensor failure).
- 4. The STEER ANGLE has a drift (it could occur also when the truck is standing) for noise captured on the encoder channels

34) WATCHDOG

Alarm 0xFF08=8 Group #0 [M,S]:

- Cause: MuC and SuC communicate on a local Can Bus communication system. Communication between them requires a stuffing bit (stuffing bit must be reversed at any new frame). In case the stuffing bit is frozen longer than 100msec this alarm occurs.
- Remedy: If it is repetitive, it reports a problem in the controller

35) CURRENT GAIN

Warning with eps on 0xFFE1=225 [M,S]:

- Cause: This alarm occurs when the gains of the current amplifiers (ADJUSTMENT #03 and ADJUSTMENT #04) are set to their default values (Imax has not been regulated yet).
- Remedy: Call Zapi assistance or replace the control.

36) SPEED SENSOR KO

Alarm 0xFF54=84 Group #2 [M,S]:

- Cause: This alarm occurs in case of a short circuit between the two stepper motor channels (QL on CNA#17 and DL on CNA#20) longer than 128msec for MuC (224msec for SuC).
- Remedy: Check for a short circuit in the wires connected to CNA#20 and CNA#17. The short circuit likely is in the path from the stepper motor to the CNA#17 and CNA#20 pins.

37) FB JERK

Alarm 0xFFDF=223 Group #3 [M,S]:

- Cause: This alarm occurs in case the position of the steered wheel measured with the encoder has a step (discontinuity) larger than 21degrees (244/4096 revolution) within 16msec and the step don't go back to a lower gap for 13 consecutive samples (total 208msec).
- Remedy: Disturb or defect in the encoder and encoder's wires. One possibility is the correct 90 degrees phase shift between CHA and CHB in the encoder has been lost.

38) STEPPER MOT MISM

Alarm 0xFFDB=219 Group #2 [M]:

- Cause: This alarm occurs two ways:
 4. Stepper motor D and Q channels are processed two ways: A/D conversion and quadrature encoder interface. When the A/D conversion supplies fast motion (D or Q line amplitude larger than 4.6Vpeak) and the quadrature encoder supplies slow motion (lower than 2 pulses within 80msec: i.e. 25Hz) longer than 200msec.
OR
 5. In case the peak value of one stepper motor channel (DL or QL) is lower than 0.61V meanwhile the peak value of the second channel is higher than 2V longer than 120msec (it

- Remedy: detects a short circuit between one stepper motor channel and GND).
Check there is not a short circuit between CNA#20 or CNA#17 and GND. Check the stepper motor is a validated model one. If it is, check the harness from the stepper motor to the controller. If nothing is found replace the stepper motor and, in case the problem remains, replace the controller.

39) WRONG RAM MEMORY

Alarm 0xFFD4=212 Group #0 [M,S]:

- Cause: This alarm occurs two ways:
 1. The process (execution of the code) omitted to pass through one (at least) of the main steps of the code flow longer than 80msec (i.e. function to read the inputs, functions to calculate the set points for the steering motor, function to supervise the state of the steer, ISRs for actuating the motor control).
OR
 2. Deterministic Finite Automaton (DFA) is characterized by state transitions. As a protective measure any state transition is commanded by assigning two variables (state label and its complement). These two variables identify the new state (redundancy in the state label). This redundancy has been thought in order to avoid that a failure in the RAM memory leads to a wrong destination state for the DFAs. In case the two state labels are inconsistent or not complemented in between, this alarm occurs.
- Remedy: If it is repetitive, it reports a problem in the controller.

40) CAN BUS KO M/S

Alarm 0xFFD7=215 Group #0 [M,S]:

- Cause: MuC and SuC communicate via a local (embedded) Can Bus communication system. If a node does not receive any response from the other node longer than 100msec, this alarm occurs.
- Remedy: If it is repetitive, it is a problem in the steering controller.

41) PARAM RESTORE

Alarm 0xFFD5=213 Group #0 [M,S]:

- Cause: This is a confirmation that a clear eeprom parameter was correctly performed.
- Remedy: Recycle the key

42) LOGIC SUPPLY ERR

Alarm 0xFFFF0=240 Group #0 [S]:

- Cause: This alarm occurs in case the 13.5V logic supply voltage to drive the three phase power bridge is detected lower than 11Vdc.
- Remedy: Recycle the key. If it is repetitive, it reports a problem in the controller

43) W.D. SYNCHRO

Alarm 0xFFD1=209 Group #0 [S]:

- Cause: Every 32 detections of the Inputs (analog and digital) (i.e. every 4msec) MuC generates a falling edge on an input of the SuC

used as an Interrupt Request. This IR works as a synchronism for SuC to start the first of 32 Inputs detections. When MuC has completed the second A/D conversion (second of 32 AD conversion in autoscan mode), it triggers the Synchro input to a high level again. SuC raises this alarm when no falling edge is detected on this synchro input longer than 90msec.

- Remedy: Recycle the key. If it is repetitive, it reports a problem in the controller. It could be an ESD problem too.

44) CAN BUS WARN

Alarm 0xFFCE Group #3=206 [M,S]:

- Cause: If a node does not receive the Traction Can Bus message (Can ID 0x388 for MuC and 0x389 for SuC) longer than 200msec, this alarm occurs.
- Remedy: Problem can be in the Can Bus wires, or in the Can Bus transceiver inside Traction, Eps or another unit in the truck. Identification of the root of the problem needs a Can Bus analyzer.

45) OUT1 STB I HIGH

Warning with eps on 0xFFEC=236 [M,S]:

- Cause: If the output of the amplifier to measure the current in the load connected to CNA#10 is not Zero at rest, this alarm occurs. Zero for MuC is 0.5V (alarm when it is higher than 2V). For MuC, output of the current amplifier increases when the current is not null. Zero for SuC is 4.5V (alarm when it is lower than 3V). For SuC, the output of the current amplifier decreases when the current is not null.
- Remedy: It reports a problem in the controller.

46) OUT1 SRT/VOLT KO

Warning with eps on 0xFFEB=235 [M,S]:

- Cause: This diagnosis is processed only at key on the Circuit in Fig. 15.46-1. Two tests:
Q3 is initially off: CNA#9 is expected to be lower than 5Vdc. In case it isn't this alarm occurs; otherwise Q3 is switched on.
Q3 is on: CNA#9 is expected to be higher than 60% of the DC bus. In case it isn't this alarm occurs.
- Remedy: It reports either a short circuit to GND of the load connected to CNA#9 or a problem in the controller (on safety switch Q3).

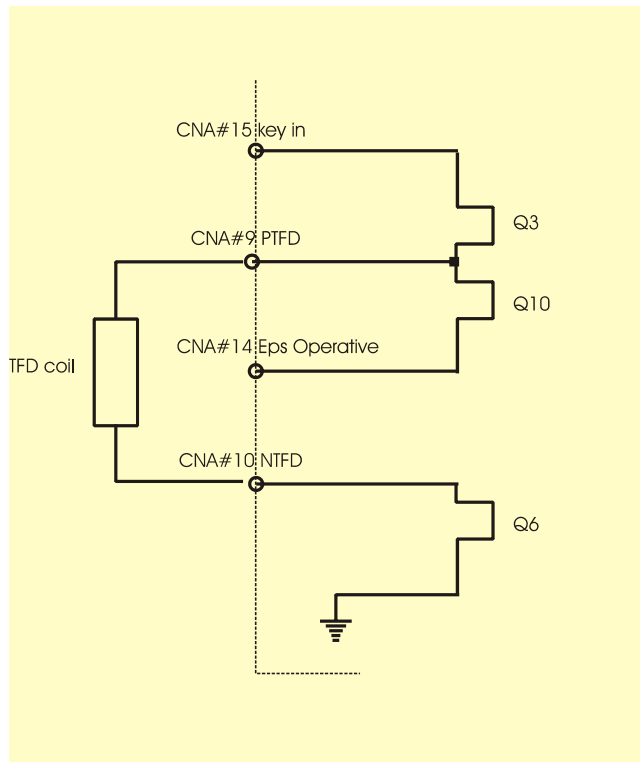


Figure 15.46-1

15.3 Alarms in selfcheck ROUTINES

Following alarms occur only when the response of a selfchecking routine (SELFCHECK#1 or SELFCHECK#2) at the end of the data collection, reports a problem in a component of the steering system (see 14 – TROUBLESHOOTING STRUCTURE).

SELFCHECK#1 checks motor and controller (three phase power bridge).

SELFCHECK#2 checks encoder and mechanics (transmission, gears, ball bearings).

1) SELFCHECK #1

Warning 0xFE00=205 [M,S]:

- Cause: This warning occurs when the SELFCHECKING routine #1 is in progress and the check result has not been determined yet. This selfchecking routine carries out a voltammeter measure of the motor resistances between phase V and W (Rvw) and between phase W and U (Rwu) by injecting a fixed 14.7A_{dc} current . The goal of this selftest is to check the functionality of motor and three phase power bridge. After the gathered data have been processed and an unexpected result occurred, this warning message will turn in an alarm information (see below).
- Remedy: recycle the key to exit the SELFCHECK #1 warning

2) CHECK #1 OK

Warning 0xFE0F=205 [M] :

- Cause: This alarm occurs only as a response of the SELFCHECK #1. It occurs in case the selfcheck #1 has passed. Condition for

passing selfcheck #1 are:

Current VW and WV close to 14.7Adc

AND

Current UW and WU close to 14.7Adc

AND

Motor resistance VW and WU in the range 180 to 380 milliohms

- Remedy: Motor and Controller work properly.

3) SELCK 1.1 VBATT

Alarm 0xFE01=205 [M]:

- Cause: This alarm occurs only as a response of the SELFCHECK #1. It occurs in case the DC Bus (between +B and –B posts) is lower than 29V (for 48V battery) and 19V (for 24V battery).
- Remedy: It reports a failure on the cable between plus or minus battery and the controller.

4) SELCK 1.2 MOT VW

Alarm 0xFE02=205 [M]:

- Cause: This alarm occurs only as a response of the SELFCHECK #1. It occurs in case the linked voltages between terminal V and W (Vvw and Vwv) to get the expected current (14.7Adc) are both higher than 10Vdc.
- Remedy: It reports a failure with terminal W or terminal V of the motor (interrupted).

5) SELCK 1.3 MOT WU

Alarm 0xFE03=205 [M]:

- Cause: This alarm occurs only as a response of the SELFCHECK #1. It occurs in case the linked voltages between terminal W and U (Vwu and Vuw) to get the expected current (14.7Adc) are both higher than 10Vdc.
- Remedy: It reports a failure with terminal U or terminal W of the motor (interrupted).

6) SELCK 1.4 CTL VW

Alarm 0xFE04=205 [M]:

- Cause: This alarm occurs only as a response of the SELFCHECK #1. It occurs in case only one between the linked voltages at terminals V and W (Vvw or Vwv) to get the expected current (14.7Adc) is higher than 10Vdc.
- Remedy: It reports a failure (interruption) in a power mosfet in the half bridges of terminals V or W.

7) SELCK 1.5 CTL WU

Alarm 0xFE05=205 [M]:

- Cause: This alarm occurs only as a response of the SELFCHECK #1. It occurs in case only one between the linked voltages at terminals W and U (Vwu or Vuw) to get the expected current (14.7Adc) is higher than 10Vdc.
- Remedy: It reports a failure (interruption) in a power mosfet in the half bridges of terminals W or U.

8) SELCK 1.6 CTL KO

Alarm 0xFE06=205 [M] :

- Cause: This alarm occurs only as a response of the SELFCHECK #1. It

- Cause: occurs in case none of the above failures has been detected but at least one between the injected currents (Ivw, Iwv, Iwu, Iuw) is lower than 10Adc (when 14.7Adc are expected instead).
- Remedy: It reports a generic failure in the controller (power or logic).

9) SELCK 1.7 STA #1

Alarm 0xFE0E=205 [M]:

- Cause: This alarm occurs only as a response of the SELFCHECK #1. It occurs in case the selfcheck #1 has not been passed but none of the above failure conditions has been detected.
- Remedy: Only deepen analysis and interpretation of STATUS#1 (see TESTER menu) may help to finalize the troubleshooting.

10) SELFCHECK #2

Warning 0xFE10=204 [M,S]:

- Cause: This warning occurs when the SELFCHECKING routine #2 is in progress and the check result has not been determined yet. This selfchecking routine carries out an embedded monitoring of the encoder and of the current in the motor when commanded to move at a fixed speed of 25Hz. We suggest to launch SELFCHECK #2 with the steered wheel lifted up. The goal of this selftest is to check the functionality of encoder and mechanical components (transmission, sensor bearings, gears, pinion). After the gathered data have been processed and an unexpected result occurred, this warning message will turn in an alarm information (see below).
- Remedy: recycle the key to exit the SELFCHECK #2 warning

11) CHECK #2 OK

Warning 0xFE1F=204 [M]:

- Cause: This alarm occurs only as a response of the SELFCHECK #2. It occurs in case the selfcheck #2 has passed. Condition for passing selfcheck #2 are (motor is turning at a fixed speed of 25Hz and the average Encoder increment is expected to be 6.42 in 16msec):
Motor Current lower than 6.5Arms
AND
Encoder Increment higher equal than 4 in 16msec
AND
Encoder Increment lower equal than 8 in 16msec
- Remedy: Encoder and Transmission work properly.

12) SELCK 2.1 VBATT

Alarm 0xFE11=204 [M]:

- Cause: This alarm occurs only as a response of the SELFCHECK #2. It occurs in case the DC Bus (between +B and -B posts) is lower than 29V (for 48V battery) and 19V (for 24V battery).
- Remedy: It reports a failure on the cable between plus or minus battery and the controller.

13) SELCK 2.2 ENC LO

Alarm 0xFE12=204 [M]:

- Cause: This alarm occurs only as a response of the SELFCHECK #2. It occurs in case the minimum encoder increment in 16msec has been detected lower than 2 (valley detection) and the average

current in the motor has been detected lower than 20Arms.
Note: at fixed 25Hz the average encoder increment is expected to be 6.42 in 16msec.

- Remedy: It reports a temporary valley in the encoder increment. Reason could be a noise in the encoder, a bad encoder connection or a local point in the steered wheel revolution with a higher friction required (local increment of friction).

14) SELCK 2.3 ENC HI

Alarm 0xFE13=204 [M]:

- Cause: This alarm occurs only as a response of the SELFCHECK #2. It occurs in case the maximum encoder increment in 16msec has been detected higher than 8 (peak detection) and the average current in the motor has been detected lower than 20Arms.
Note: at fixed 25Hz the average encoder increment is expected to be 6.42 in 16msec.
- Remedy: It reports a temporary peak in the encoder increment. Reason could be a noise in the encoder, a bad encoder connection or the friction throughout a whole steered wheel revolution is not constant (changes or steps in the friction within a whole revolution).

15) SELCK 2.4 IMAX

Alarm 0xFE14=204 [M]:

- Cause: This alarm occurs only as a response of the SELFCHECK #2. It occurs in case the average encoder increment in 16msec has been detected lower than 4 (motor doesn't reach commanded 25Hz speed) and the average current in the motor has been detected higher than 40Arms.
Note: at fixed 25Hz the average encoder increment is expected to be 6.42 in 16msec.
- Remedy: There are two possibilities:
 - 1) if the steered wheel MOVES VERY SLOWLY, likely an encoder failure occurred.
 - 2) if the steered wheel DO NOT MOVE, likely a too friction or even mechanical lock in the transmission (sensor bearings, gears) occurred.

16) SELCK 2.5 I > 20A

Alarm 0xFE15=204 [M]:

- Cause: This alarm occurs only as a response of the SELFCHECK #2. It occurs in case the average encoder increment in 16msec has been detected very close to the expected (higher than 6) and the average current in the motor has been detected higher than 20Arms (overload).
Note: at fixed 25Hz the average encoder increment is expected to be 6.42 in 16msec.
- Remedy: There are two possibilities:
 - 1) if the steered wheel is lifted up, this alarm reports to a condition with too much friction required to steer (ball bearing or transmission defected).
 - 2) if the steered wheel is on the floor instead only a test with the steered wheel lifted up may confirm the high friction is generated inside the system (e.g. failure in the ball bearings or transmission) and not for an external physiological condition (e.g. hard floor or wheel

overloaded).

17) SELCK 2.6 I > 10A

Alarm 0xFE16=204 [M]:

- Cause: This alarm occurs only as a response of the SELFCHECK #2. It occurs in case the average encoder increment in 16msec has been detected very close to the expected (higher than 6) and the average current in the motor has been detected higher than 10Arms (too high for a lifted up steered wheel).
Note: at fixed 25Hz the average encoder increment is expected to be 6.42 in 16msec.
- Remedy: This situation is physiological when the steered wheel is on a flat surface (we have measured 12Arms to steer an unloaded truck @ Tamb=25°C). This situation must be investigated in case it occurs with the steered wheel lifted-up (only very low Tamb could physiological affect significantly the friction in the transmission).

18) SELCK 2.7 POWER

Alarm 0xFE17=204 [M]:

- Cause: This alarm occurs only as a response of the SELFCHECK #2. It occurs in case the current in the motor does not reach the commanded value for turning the motor at 25Hz.
- Remedy: it reports a problem in the power actuator of the system (including 3phase power bridge and motor). A SELFCHECK #1 test may help to clarify if the problem is in the motor or in the controller.

19) SELCK 2.8 STA #2

Alarm 0xFE1E=204 [M]:

- Cause: This alarm occurs only as a response of the SELFCHECK #2. It occurs in case the selfcheck #2 has not been passed but none of the above failure conditions has been detected.
- Remedy: Only deepen analysis and interpretation of STATUS#2 (see TESTER menu) may help to finalize the troubleshooting

15.4 CAN BUS “ALARMS” List

The Alarm Code List supplied by the Master Microcontroller (MuC) in the epsacW (Source Device Code #18 for the CAN Console and #06 for the remote Zapi hand set) is the following:

8:	WATCH DOG
13:	EEPROM KO
16:	LOGIC FAILURE #4
17:	LOGIC FAILURE #3
32:	VMN NOT OK
48:	MAIN CONT. OPEN
53:	STBY I HIGH
60:	CAPACITOR CHARGE
61:	HIGH TEMPERATURE
65:	MOTOR TEMPERAT.
70:	HIGH CURRENT
71:	POWER FAILURE #3
72:	POWER FAILURE #2
73:	POWER FAILURE #1
81:	BAD STEER 0-SET
84:	STEER SENSOR KO
85:	STEER HAZARD
204:	SELFCHECK #2
205:	SELFCHECK #1
206:	CAN BUS WARN
210:	WRONG SLAVE VER
212:	WRONG RAM MEMORY
213:	PARAM RESTORE
215:	CAN BUS KO M/S
219:	STEPPER MOTOR MISM
220:	MOTOR LOCKED
221:	M/S PAR CHK MISM
223:	FB JERK
225:	CURRENT GAIN
228:	POSITION ERROR
235:	OUT1 SRT/VOLT KO
236:	OUT1 STB I HIGH
237:	SLAVE ALARM
238:	EPS NOT ALIGNED
240:	LOGIC SUPPLY ERR
241:	FB SENS LOCKED
242:	Q LINE SENSOR KO
243:	D LINE SENSOR KO
244:	PARAM TRANSFER
245:	DATA ACQUISITION
247:	CAN BUS KO
251:	INIT VMN NOT OK
253:	ANALOG

The Alarm Code List supplied by the Slave Microcontroller (SuC) in the epsacW

(Source Device Code #19 for the CAN Console and #38 for the remote Zapi hand set) is the following:

8: WATCH DOG
13: EEPROM KO
16: LOGIC FAILURE #4
17: LOGIC FAILURE #3
32: VMN NOT OK
48: MAIN CONT. OPEN
53: STBY I HIGH
70: HIGH CURRENT
81: BAD STEER 0-SET
84: STEER SENSOR KO
206: CAN BUS WARN
207: SP MISMATCH
208: OUTPUT MISMATCH
209: W.D. SYNCHRO
212: WRONG RAM MEMORY
213: PARAM RESTORE
215: CAN BUS KO M/S
220: MOTOR LOCKED
223: FB JERK
225: CURRENT GAIN
235: OUT1 SRT/VOLT KO
236: OUT1 STB I HIGH
237: WAITING MASTER
238: EPS NOT ALIGNED
240: LOGIC SUPPLY ERR
241: FB SENS LOCKED
242: Q LINE SENSOR KO
243: D LINE SENSOR KO
247: CAN BUS KO
250: INPUT MISMATCH
253: ANALOG

16 SAFETY REQUIREMENTS & RECOMMENDATIONS



According EN1175 and ISO13849, we consider the arrangement documented in this manual suited to work in Manual Mode and Loop Mode only (target is PLd and Category #3). Obviously, the lift truck manufacturer is responsible for the final system and, to fulfil the norms, the lift truck manufacturer is called to adopt special analysis, design principles and cares against the faults of the components of the system that are not in charge of Zapi but affect the safety. Particular attention must be paid for those of these components which cannot be monitored/ diagnosed by the Zapi assembly (let's consider an example: the shaft of the Steering Wheel is totally in charge of the Lift Truck manufacturer and there is no chance the Zapi system can detect a failure in that component. This component, in case fails to a loosened condition, compromises the safety). These analysis, design principles and cares pass through two steps:

- 1) The lift truck manufacturer, according its own FMEA can conclude that, a fault in a component that is not redundant (and not covered by the diagnosis), shall not lead to a lost of safety (no countermeasure required).**
- 2) The lift truck manufacturer, according its own FMEA can conclude that, a fault in a component that is not redundant (and not covered by the diagnosis), shall lead to a lost of safety (a failure of that component must be avoided with proper cares: fault exclusion case).**



VERY IMPORTANT: among the components of the system that are not in charge of Zapi there is the unit in the truck designated to lead the traction to a safe state in case of an alarm in the steering system (typically a VMC = Vehicle Master Control; but in general it can be any unit in the truck. In the next we refer to this unit as a TMC= Traction Master Control). This is a major safety issue and the LIFT TRUCK MANUFACTURER is responsible for coordinating the communication between different suppliers and furthermore for testing and validating that this alarm information will be properly handled in the destination site and leading to a traction safe state when the steering system is no longer operative. This problem is even more dramatic in case the unit assigned to stop the traction IS NOT A ZAPI unit (see also 16.2).

16.1 Fault exclusions

16.1.1 Mechanical coupling



According EN1175 and ISO13849, a case of fault exclusion must be applied to the mechanical coupling between motor shaft and steered wheel. The

chain involves the motor pinion, the gear box and the external gears. Never this chain is allowed to loose its driving force. If the lift truck manufacturer excludes a fault, a detailed justification shall be given in the documentation (see ISO13849-1 topic 7).

16.1.2 Straight ahead switch (SW1)



Another single component is the straight ahead switch (SW1). In case it toggles not in the straight direction, the steered wheel will be aligned at key-on to a wrong direction. So a decision on the related risk must be taken and eventually SW1 fault must be excluded.

In case the lift truck manufacturer considers not practicable to exclude SW1 fault, it is possible to test the straight ahead switch at key-on with the following handling (currently not implemented).

16.1.2.1 Diagnosis of the straight ahead switch at key-on



With software modifications, it could be possible to make a test at key-on on the straight ahead switch by comparing the current detection of the straight ahead position (at SW1 edge) with the straight ahead position expected if the initial angle of the steered wheel at key-on is coincident with the last angle before turning off the key (and recorded in EEPROM).

In case of a mismatch, the truck speed shall be reduced to a very low value and the driver is called for a manoeuvre (like spinning the steering wheel until SW2 toggles) to have confirmed SW1 toggled in the correct direction before the truck is allowed to speed up. This handling involves more modules in the truck and it can annoy the driver because the steered wheel can move by itself when the key is off (and so th-driver will be asked for spinning the steering wheel on SW2 at the next key-on). For that reason it will be implemented only on lift truck manufacturer's demand (Note: when this manual has been compiled (SW NA4.98) this function was not implemented).

16.1.2.2 Involving 90 degrees switch (SW2) for the max angle limitation



90 degrees switch (SW2) may be used to fight the following failure effect analysis. If the straight ahead switch (SW1) toggles not in the straight direction, the steered wheel will be aligned at key-on to a wrong direction. This situation may affect the max angle limitation. For instance, in case the straight ahead switch toggles at +30° (real angle) at key-on, the max angle limitation via encoder counting occurs in the range +30° +/- 90 degrees (i.e. at -60° and +120°). On the +120° direction, the failure in SW1 will be detected by the POSITION ERROR when SW2 toggles (real angle is +90°) and the measured angle is only (+90° - 30°) = +60°; in the other direction, the steered wheel angle will be limited to a (real) steered wheel angle of -60°

before SW2 toggles. This is a safety relevant issue and should be avoided. To do that it is possible to involve the 90 degrees switch (SW2) to limit the angle (i.e. the angle will be limited when two conditions occur):

- a) encoder counting overtakes the max angle setting*
- AND*
- b) the 90 degrees switch (SW2) toggles*

To enable this handling, turn option SW2 LIMITING to ON.

16.2 Safety Function to stop the Traction following an epsacW alarm



In case of an alarm in the steering system, the job in the Zapi steering assembly finishes when the STOP TRACTION REQUEST info (Bit in a PDO) and the alarm code (EMERGENCY or PDO frame) has been released on the CAN BUS (ask the object dictionary to the Zapi technicians). The procedure to turn the traction to a safe state when the steering system reports an alarm is FULLY UNDER THE RESPONSABILITY OF THE LIFT TRUCK MANUFACTURER and so he has to take care this procedure will be 100% effective. Furthermore, special cares are recommended in case the module designated to lead the traction to a safe state (Traction Control Module = TMC) IS NOT A ZAPI's UNIT (ask to Zapi technicians for properly coordinating the communication between EpsacW and TMC).

16.3 Vehicle Master Control (VMC) Safety Functions



Together with the safety function to stop the traction (see topic 16.2) the VMC in general has a second Safety Relevant function: it sends a PDO to the EpsacW to turn the steering control from rest to Operational. Typical situation is:

- 1) A main contactor, driven by the VMC or by another unit in the truck, supplies the Battery Power to the EpsacW.*
- 2) The EpsacW is expected to stay at rest until the main contactor will be closed (to avoid unwilling alarms).*
- 3) VMC will communicate on a PDO (VMC -> EpsacW) when the main contactor has been closed and the EpsacW turns Operational.*

This function is Safety Relevant because, the event with the VMC commands the traction moving and forgets to command the steering to Operational leads to an unsafe situation (traction moving and no steer). This is a single fault leading to a lost of safety. So, for fulfilling with ISO13849, this Safety Function of the VMC should be designed according the PLd and Category #3 requirements.

A good practice to avoid this constrain could be:

- 1) Do not connect the EpsacW under the main contactor driven by the VMC*

BUT

2) Connect the EpsacW directly to the Battery rail (as consequence the EpsacW is always Operational).

OR

2bis) Connect the EpsacW under a line contactor that the EpsacW switches on immediately at key on.

As a consequence, in both cases 2) and 2bis), EpsacW will be always Operational independently by the traction is REALLY moving or not.

16.4 Closed Loop Mode



According EN1175 and ISO13849 we consider the arrangement documented in this manual suited to work in Manual Mode and Open Loop Mode only. If Closed Loop mode will be required (like truck travels Automatic Centered or Wire Guided or Manual Mode in Closed Loop), a different feedback arrangement adopting a second encoder in the steering motor is strongly recommended.

Closed loop functions already implemented in this system (recovery at rest and max angle limitation) are not considered Safety Relevant because of two reasons:

1) These secondary closed loop functions are executed with a very slow steering motor and only in case the steering wheel is released

AND

2) As soon as the driver moves the steering wheel the closed loop function is immediately aborted (Open loop function is dominant ever).

16.5 Safety relevant parameters



Many of the parameters used in this application are Safety Relevant. Despite of that, it is a common practice the final lift truck manufacturer has its own tool for setting the parameters on its demand on the field. This handling is Safety Relevant and, for fulfilling with ISO13849, this set-up tool should be designed according the PLd and Category #3 requirements. Besides only skill and well trained technicians are allowed to change these safety relevant parameters.

So:

1) Zapi is available for supporting the lift truck manufacturer to list the safety relevant parameters.

2) Zapi is also available for limiting the rights to change these safety relevant parameters on the user demand.

3) Zapi is not responsible if, whatever is the reason, a safety relevant parameter will be improperly changed by the user.

16.6 Safety relevant notes



The recommendations of this manual underlined with the attention symbol



, are safety relevant and so the user is recommended to accurately read and take care of these paragraphs and notes and ask for the Zapi support in case something is not clear.

17 INSTALLATION REQUIREMENTS & RECOMMENDATIONS

1. **IMPORTANT 1: TAKE CARE THE CONNECTOR COUNTERPARTS (HEADER PINS AND RECEPTACLE CONTACTS) ARE CHEMICALLY HOMOGENEOUS.**

EpsacW adopts a 23poles AMPSEAL header tin plated connector. So the contacts in the counterpart must be tin plated too. In case a gold plated type AMPSEAL connector will be used in the epsacW side, the contacts in the counterpart must be gold plated too.

2. **IMPORTANT 2: DO NOT CONNECT A LIVE BATTERY TO THE EPSACW +B and -B CONNECTIONS.** A live battery generates a conflict with the discharged caps rail inside the epsacW: a consequent spark will damage (melt) the pins of the connector. **Keep the battery unplugged when connecting the receptacle to its header counterpart.**

3. **IMPORTANT 3: TAKE CARE YOUR FINGERS STAYS AWAY FROM THE PINS OF THE EPSACW CONNECTOR DURING INSTALLATION.** The fingers can bend or contaminate the pins.

18 PERIODIC MAINTENANCE TO BE REPEATED AT TIMES INDICATED

Check the screws to couple the steering gear box to the truck frame are tightened. They should be checked every **3 months**.

Check the screws to couple the steering gear box to the motor are tightened. They should be checked every **3 months**.

Check the screws to couple the steering motor flanges are tightened. They should be checked every **3 months**.

Check the wires in the ampseal connector are tightened. Ensure the female connector is tightly coupled with its counterpart. Wires should be checked 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.

18.1 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):

Switch on the key and try to disconnect the stepper motor. An alarm, stopping the traction should immediately occur

Try to disconnect the +B to the steering assembly. After switching on the key an alarm stopping the traction should immediately occur as soon as the steering (or handle) wheel rotates
