AC Asynchronous/Synchronous Motor Controller

USER MANUAL

(Rev. 1.0: March 2017)

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Model

AC-X1

With 12-24V Isolated Logic Section

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1. Introduction

1.1 About SME Company

SME group, founded in 1974, is a high technology company, manufacturer of electronic controllers and related products for application in battery powered vehicles, particularly forklift trucks and specialized in the development of AC power controllers.

The group provides intelligent and innovative solutions to satisfy market requirements, achieving worldwide customer satisfaction.

1.2 About this manual

This manual contains information about a motor controller intended for electric vehicles using 100V for high power circuits and a 12V or 24V isolated logic section for low power circuits.

This version replaces all previous existing versions of the manual, if any.

1.3 About warning, caution and information notices

Special attention must be paid to the information presented in Warning, Caution and other kinds of information notices when they appear in this manual.

Failure to follow those recommendations may result in dangerous situations or in damages to the components, for which SME will not respond.

Warnings. A Warning informs the user of a hazard or a potential hazard which could result in serious or fatal injury if the precautions or instructions given in the warning notice are not observed.

Cautions. A caution informs the reader of a hazard or a potential hazard which could result in a serious damage to the appliance.

Information Notices. An information notice contains additional, not essential pieces of information to complete or to clarify the meaning of the paragraph they are placed into.

Interactive Documentation Tips: An advice about where to find the related section in the Interactive Documentation

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1.4 Product warranty information

SME offers a two-year warranty on all the products, unless a different agreement has been put in place. Refer to the sales agreement or contract under which the *motor controller* was purchased for a complete statement of the product warranty.

1.5 How to find us

For any information on commercial and technical issues, please contact either your dealer or SME at the following address for your region:

SME Group Head Office (Europe)

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2. AC SmartMotion AC-X1 Overview

Figure 1 *- AC-X1*

2.1 Product description

The AC-X1 Controller is designed to control AC Asynchronous and Synchronous motors.

Being based on high reliable DCB technology and exceptionally stable Field Oriented Control (FOC) Algorithm, AC-X1 Controller is a revolutionary and high quality solution for medium power applications.

The product is suitable for the following range of applications: Counterbalanced Lift Trucks, Cleaning Machines, Golf cars, Aerial Lifts, Tractors, Utility Vehicles, Tow Trucks.

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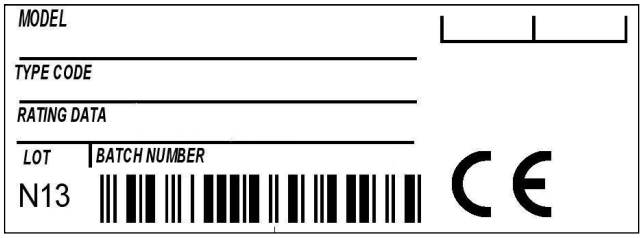
2.1.1 Product Indication Label

The product label shows important data regarding the specific product.



The meaning of each field is described in the table below.

Field	Description
Model	Product description.
Type Code	SME code for the specific product.
Rating Data	It contains the indication of the input voltages and the output currents supplied by the product.
Batch Number	Production batch number (the same value as in barcode below).
Lot	Production Month and Year

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2.2 General Specifications

- **Motor Type:** AC Asynchronous and Synchronous motors
- **Braking:** Regenerative
- **Modulation:** PWM (Pulse Width Modulation)
- **Switching Frequency:** 9kHz
- **Low $R_{DS,on}$ MOSFET**
- **16 bits DSP** controlling 1 AC motor
- **Integrated Hall Effect Current Sensors**

2.3 Electrical Specifications

2.3.1 Input and Output Ratings

Model Chart for 120/144V version		
Model Name	**Current 2 min. rating**	**Power 2 min. rating at 120V**
AC-X1 120/144V 250A	250 A_{rms}	41.6kVA
AC-X1 120/144V 500A	500 A_{rms}	83.1kVA

Model Chart for 80/100V version		
Model Name	**Current 2 min. rating**	**Power 2 min. rating at 80V**
AC-X1 80/100V 250A	250 A_{rms}	27.7kVA
AC-X1 80/100V 375A	375 A_{rms}	41.5kVA
AC-X1 80/100V 500A	500 A_{rms}	55.4kVA
AC-X1 80/100V 625A	625 A_{rms}	69.2kVA
AC-X1 80/100V 750A	750 A_{rms}	83.0kVA

Notes: 2-minute ratings are based on an initial controller baseplate temperature of 25°C and a maximum baseplate temperature of 85°C.

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2.3.2 Signal: Inputs and Outputs

- **Digital Inputs:** 9
- **Analog Inputs:** 5
- **Digital Outputs (ON/OFF):** 2
- **Driver Outputs (PWM):** 4
- **Motor Speed Sensor Inputs:** 2 (A+B Channels or Sin + Cos Inputs)

Refer to following tables for a complete AC-X1 controller K1 and K3 connectors pin-out.

K1 connector pin-out for AC-X1				SPECIFICATIONS
Pin	**Name**	**I/O**	**Specification**	**Typical Function**
1	NEGATIVE KEY SUPPLY	I/O Ground	Do not exceed 0.5A	Negative Key Supply
2	CAN-L	CAN BUS	CAN-BUS 1 MBit/s max	CAN L
3	CAN-L RES	CAN BUS	Connected to CAN-L with a series 120Ohm	Termination resistor
4	DIGITAL INPUT 1	Digital Input	VL<=2V, VH>=4.5V; Pull-down(active high +12V or +24V) Pull up(active low)	**TO BE ASSIGNED**
5	DIGITAL INPUT 2	Digital Input	VL<=2V, VH>=4.5V; Pull-down(active high +12V or +24V) Pull up(active low)	**TO BE ASSIGNED**
6	DIGITAL INPUT 3	Digital Input	VL<=2V, VH>=4.5V; Pull-down(active high +12V or +24V) Pull up(active low)	**TO BE ASSIGNED**
7	DIGITAL INPUT 4	Digital Input	VL<=2V, VH>=4.5V; Pull-down(active high +12V or +24V) Pull up(active low)	**TO BE ASSIGNED**
8	DIGITAL INPUT 5	Digital Input	VL<=2V, VH>=4.5V; Pull-down(active high +12V or +24V) Pull up(active low)	**TO BE ASSIGNED**
9	I/O GROUND	I/O Ground	Do not exceed 0.5A	Negative Logic Supply
10	+12V OUT	Supply Output	12V ±5% 200mA max current	12V Supply
11	ANALOG INPUT 1	Analog Input	0÷12V 125KΩ pull-down	**TO BE ASSIGNED**
12	I/O GROUND	I/O Ground	Do not exceed 0.5A	Negative Logic Supply
13	CAN-H	CAN BUS	1 MBit/s max	CAN H

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K1 connector pin-out for AC-X1				SPECIFICATIONS
Pin	**Name**	**I/O**	**Specification**	**Typical Function**
14	CAN-H RES	CAN BUS	Connected to CAN-H	Connected to CAN-H
15	LIN	Com Input/Output	19.2kbaud 12V, 1KΩ pull-up	LIN Display Connection
16	DIGITAL IN 6	Digital Input	VL<=2V, VH>=4.5V; Pull-down(active high +12V or +24V) Pull up(active low)	**TO BE ASSIGNED**
17	ANALOG INPUT 2	Analog Input	0÷12V 47KΩ pull-down	**TO BE ASSIGNED**
	0÷10V OUT	Analog Output	0÷10V max load current 5mA	**TO BE ASSIGNED**
18	DIGITAL IN 7	Digital Input	VL<=2V, VH>=4.5V; Pull-down(active high +12V or +24V) Pull up(active low)	**TO BE ASSIGNED**
19	DIGITAL IN 8	Digital Input	VL<=2V, VH>=4.5V; Pull-down(active high +12V or +24V) Pull up(active low)	**TO BE ASSIGNED**
20	DIGITAL IN 9	Digital Input	VL<=2V, VH>=4.5V; Pull-down(active high +12V or +24V) Pull up(active low)	**TO BE ASSIGNED**
21	ENCODER 1A / ENCODER 1 Sin	Peripheral Input	4V 470Ω pull-up, VL<=1.5V, VH>=3.4V / 0,5 – 4,5 mV input	Quad Encoder Channel A / Sin/Cos Encoder Sin
22	ANALOG INPUT 3	Analog Input	0÷12V 125KΩ pull-down	**TO BE ASSIGNED**
	+/- 10V	Analog Input	0÷ +10V 125KΩ pull-down, 0÷ -10V 100KΩ pull-down,	**TO BE ASSIGNED**
23	ANALOG INPUT 4	Analog Input	0÷12V 125KΩ pull-down	**TO BE ASSIGNED**
24	KEY SWITCH IN	Supply Input	Max = 18V , Min = 7V; Supply consumption: logic board 2A max + coil return 8A max	Positive Supply of the control section of the AC-X1
25	+12V COMMON	Supply Output	(+12V KEY ±0.3V) Do not exceed 8A	Positive Common of Auxiliary
26	DRIVER OUTPUT 1	PWM Output	Active low Internal diode to coil return	Main Contactor, Brake, Valve
27	DRIVER OUTPUT 2	PWM Output	Active low Internal diode to coil return	Main Contactor, Brake, Valve
28	DRIVER OUTPUT 3	PWM Output	Active low Internal diode to coil return	Main Contactor, Brake, Valve
29	DRIVER OUTPUT 4	PWM Output	Active low internal diode to coil return	Main Contactor, Brake, Valve
30	DIGITAL OUTPUT 1	Digital Output	Active low; Pull-down; No internal diode to coil return	Buzzer-Fan-ON/OFF valve

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K1 connector pin-out for AC-X1				SPECIFICATIONS
Pin	**Name**	**I/O**	**Specification**	**Typical Function**
31	DIGITAL OUTPUT 2	Digital Output	Active low; Pull-down; No internal diode to coil return	Buzzer-Fan-ON/OFF valve
32	MOTOR THERMAL PROBE	Analog Input	5V 1KΩ pull-up	Motor Temperature Probe
33	ENCODER 1B / ENCODER 1 Cos	Peripheral Input	4V 470Ω pull-up, VL<=1.5V, VH>=3.4V / 0,5 – 4,5 mV input	Quad Encoder Channel B / Sin/Cos Encoder Cos
34	ANALOG INPUT 5	Analog Input	0÷12V 125KΩ pull-down	**TO BE ASSIGNED**
35	+5V OUT	Supply Output	5V ±5% 200mA max current	12V Supply

K3 connector pin-out for AC-X1				SPECIFICATIONS
Pin	**Name**	**I/O**	**Specification**	**Typical Function**
1	-	-	-	-
2	DIAGNOSTIC RX (RS232)	Input	38.4-115.2 KBit/s	Rx Diagnosis
3	DIAGNOSTIC TX (RS232)	Output	38.4-115.2 KBit/s	Tx Diagnosis
4	-	-	-	-
5	I/O GROUND	I/O Ground	Do not exceed 0.5A	Negative Logic Supply
6	-	-	-	-
7	-	-	-	-
8	-	-	-	-
9	+5V Out	Bluetooth Supply	±10% 50mA 6Ω output impedance	Positive Logic Supply

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2.3.3 Interfaces

- **Serial Communication:** RS-232
- **CAN:**
    - **Protocol:** CAN Open
    - **Physical layer:** ISO11898-2
    - **Baud rates:** 1Mbps, 800kbps, 500kbps, 250kbps, 125kbps, 50kbps
- **Lin Bus**

2.3.4 EMC

- EN12895 (Industrial Trucks – Electromagnetic Compatibility)
- UNICE Regulation No. 10 Rev.5 (Uniform provisions concerning the approval of vehicles with regard to electromagnetic compatibility)

2.3.5 Safety

- EN1175-1 (Safety of Industrial Trucks – Electrical Requirements)

The vehicle OEM takes full responsibility of the regulatory compliance of the vehicle system with the controller installed.

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2.4 Operating Environment Specifications

- **Storage ambient temperature range:** -40°C ÷ +70°C
- **Operating ambient temperature range:** -40°C ÷ +55°C
- **Baseplate operating temperature range:** -40°C ÷ +95°C
  - ***linear current cutback, beginning at*** +85°C **(boost at 75°C)** ***down to 50% at*** +95°C
  - ***complete cutoff at*** +100°C
  - ***baseplate temperature is measured internally near the power MOSFETs.***
- **Protection Level:** IP65
- **Vibration:** Tested under conditions suggested by EN60068-2-6 [5g, 10÷500Hz, 3 axes]
- **Shock & Bump:** Tested under conditions suggested by EN60068-2-27
- **Cold & Heat:** Tested under conditions suggested by EN60068-2-1
- **Mechanical size:** 210 x 160 x 85 [mm]
- **Weight:** 3.5 kg

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3. Installation and Wiring

For specific application, refer to the About Controllers Area of the Interactive Documentation.

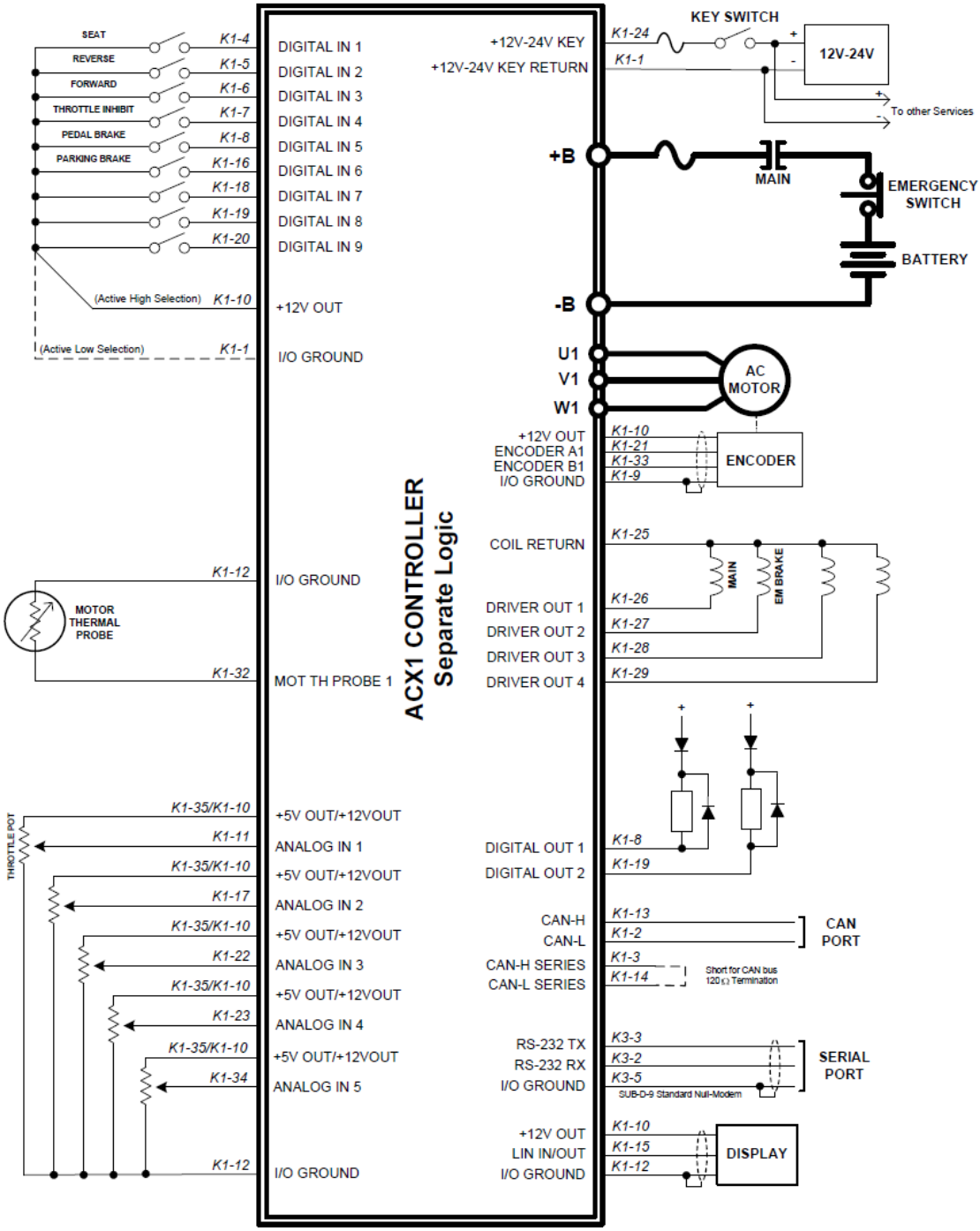

Figure 2a *- AC-X1 with Asynchronous Motor Wiring Diagram*

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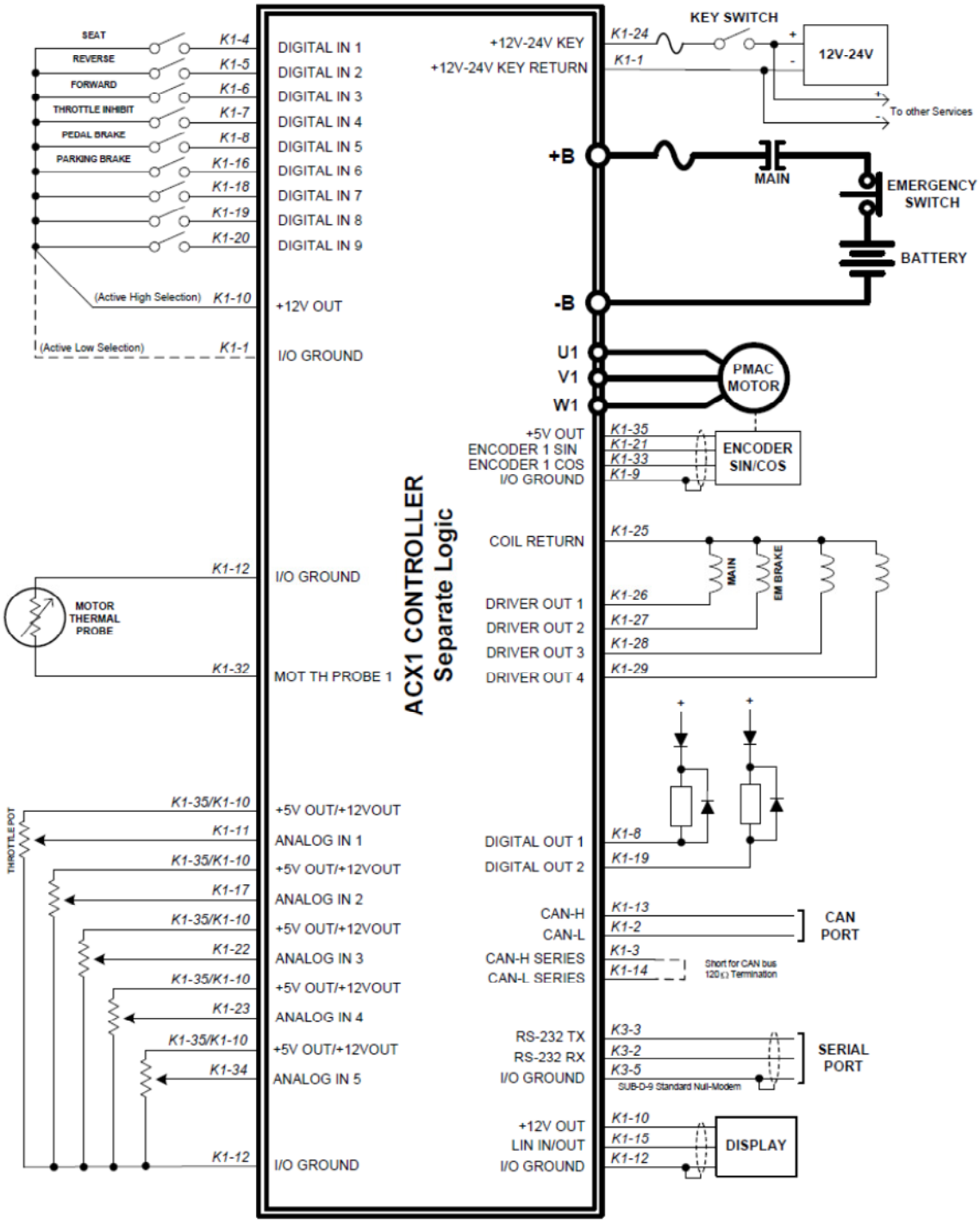

***Figure 3b** - AC-X1 with Synchronous Motor Wiring Diagram*

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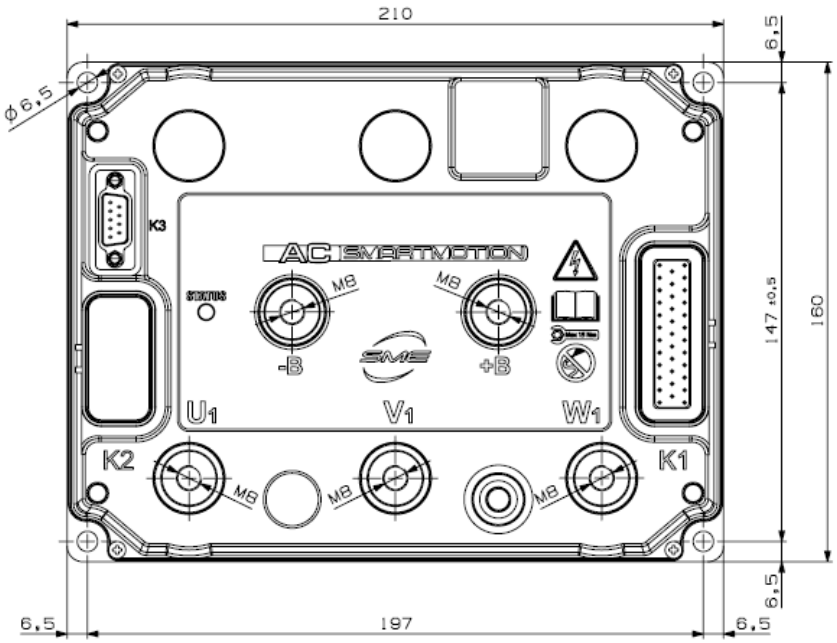
3.1 Controller

The Controller contains **ESD-sensitive components.** Use appropriate precautions in connecting, disconnecting, and handling it.

Working on electrical systems is potentially dangerous; you should protect yourself against :
Uncontrolled operation: some conditions could cause the motor to run out of control: disconnect the motor or jack up the vehicle and get the drive wheels off the ground before attempting any work on the motor control circuitry.
Voltage hazard and high current arcs: batteries can supply high voltage and very high power, and arcs can occur if they are short circuited. Always disconnect the battery circuit before working on the motor control circuit.
Wear safety glasses and use properly insulated tools to prevent shorts.
Never energize the system if the terminals –B and +B are not tightly connected.
Lead acid batteries: charging or discharging generates hydrogen gas, which can build up and go around the batteries. Follow the battery manufacturer's safety recommendations and wear safety glasses.

Mechanical Drawing

For high resolution diagram, refer to the About Controllers Area of the Interactive Documentation.



AC - X1 Top View

Figure 4 *– Top View*

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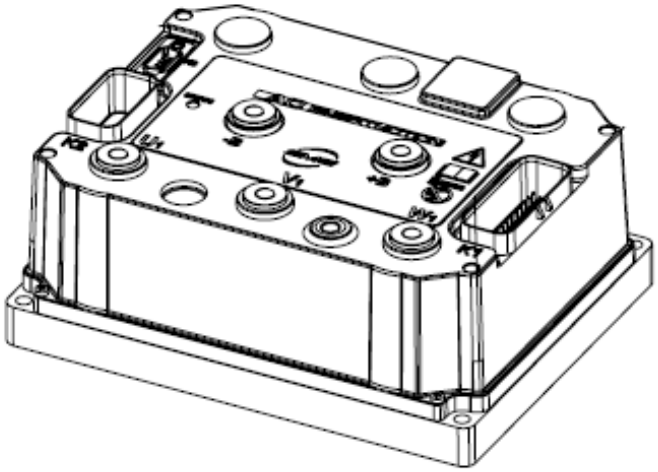
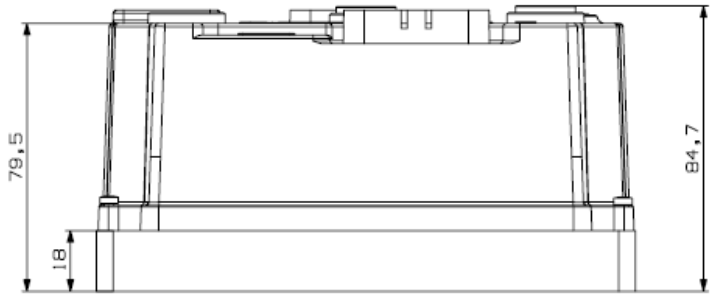


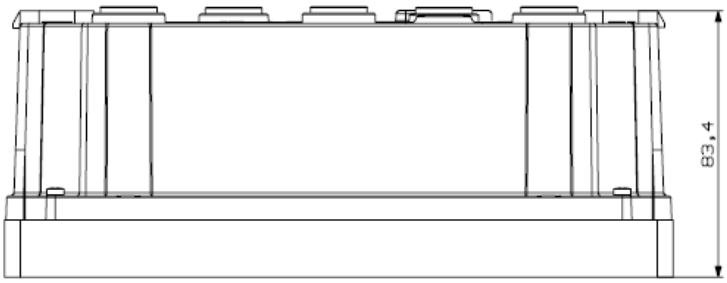
AC - X1 General View

Figure 5 *– General View*



AC - X1 Side View

Figure 6 *– Side View*



AC - X1 Back View

Figure 7 *- Back View*

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Mounting and Replacement

The Controller meets IP65 environmental protection rating against dust and water.

The mounting location should be carefully chosen in order to be clean and dry, to minimize shock, vibration, temperature changes and exposure to water & contaminants. If this kind of location can't be ensured, then a cover should be used to shield the controller. Cables must be routed to prevent liquids flowing into the connections. The mounting location should also allow access to all connections.

The replacement of the Controller must be done with the hand brake engaged, the drive wheels off the ground, the key switch in off position, battery plug disconnected and the capacitors of the inverter completely discharged.
The capacitors in the inverter can be discharged by connecting a load between the inverter's +B and –B terminals.

Cooling

The Controller must be mounted on a flat, clean and free of paint surface (external heatsink). Care must be taken to achieve maximum contact (i.e. minimum contact thermal resistance) for the best heat dissipation. When designing a cooling system, please refer to the following instructions:

1. Apply thermal compound with a good thermal conductivity on the contact surface of the controller's aluminium baseplate and the external heatsink (thermal grease thickness: +120 ÷ +150µm).
2. The surface finish of the external heatsink should be less than Rz 12µm and the flatness less than 0.5mm.

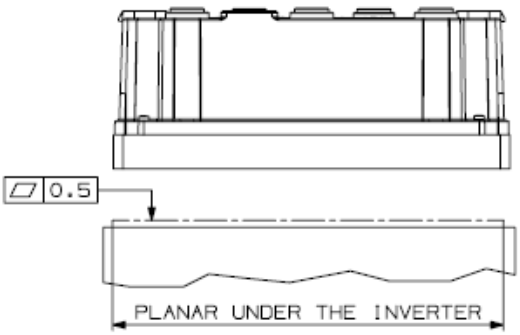

Figure 8 *– Flatness specifications*

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3. A torque wrench shall be used in tightening the 4 mounting screws. The maximum tightening torque is 6Nm. The order for mounting screws, should follow a “crisscross” pattern. The temporary tightening torque should be set at 20-30% of the maximum rating.

Clearances

For all AC-X1 models 50 mm clearances in front of and behind the AC-X1 are required for airflow; 50 mm clearance above the AC-X1 is required for installation/removal of interface connectors and wiring.

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3.2 Power Terminals

Wiring

The Controller has five Power Terminals, which are clearly marked on Controller's cover as **B+**, **B-**, **U**, **V**, **W**.

Power Terminals on Controller	
Terminal	**Meaning**
B+	Positive Battery coming from the Main Contactor
B-	Negative Battery
U	U Motor Phase
V	V Motor Phase
W	W Motor Phase

The recommended **screw torque** for fixing the Power Terminals is 15 Nm. This value is written on the label placed on the cover, exceeding the recommended value may cause damages.

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3.3 Signal

The Controller uses:

- Two Ampseal connectors:

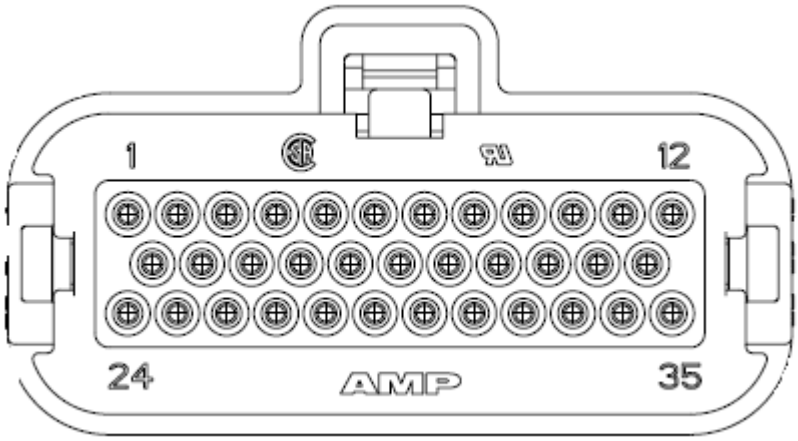

Figure 9 *- Ampseal Connector K1*

Refer to the following specifications for these connectors:

- **Number of Positions:** 35 Positions
- **Mounting Style:** Wire
- **Termination Style:** Crimp
- **Contact Type:** Plug
- **Current Rating:** 17 A
- **Housing Material:** Thermoplastic
- **Material:** Plastic
- **Number of Rows:** 3 Row
- **Packaging:** Bulk
- **Type:** Female
- **Wire Gauge Range:** 20 AWG - 16 AWG

For detailed product information, please refer to the **AMPSEAL Connectors: Product Specification 108-1329**.

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In order to ensure a fine wiring, please refer to the **AMPSEAL Automotive Plug Connector and Header Assembly: Application Specification 114-16016.**

- One SUB-D connector:

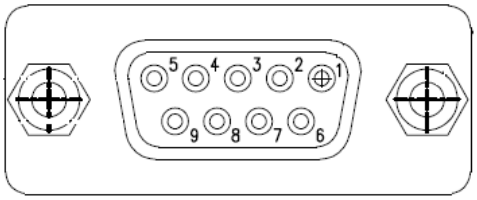

Figure 10 *- SUB-D Connectors K3*

- **Number of Positions:** 9 Positions
- **Termination Style:** Trough Hole
- **Number of Rows:** 2 Row
- **Type:** Female

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3.3.1 Digital Inputs

Digital Inputs on Controller			
Pin	**Meaning**	**Pin**	**Meaning**
K1 - 1	I/O Ground	**K1 - 10**	+12V Out
K1 - 4	Digital Input 1	**K1 - 16**	Digital Input 6
K1 - 5	Digital Input 2	**K1 - 18**	Digital Input 7
K1 - 6	Digital Input 3	**K1 - 19**	Digital Input 8
K1 - 7	Digital Input 4	**K1 - 20**	Digital Input 9
K1 - 8	Digital Input 5	**K1 - 35**	+5V Out

Wiring

Active High Selection

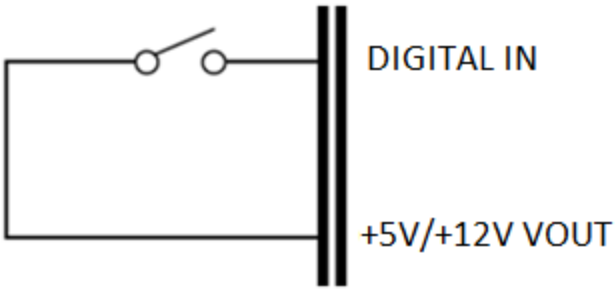

Figure 11 *- Positive Logic for Digital Input*

Active Low Selection

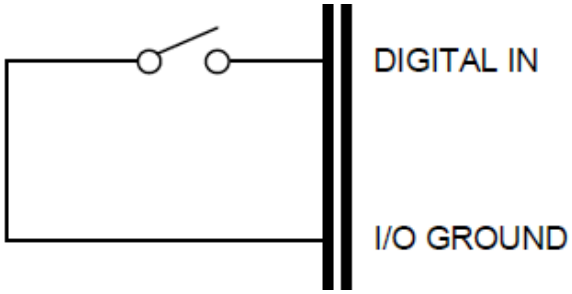

Figure 12 *- Negative Logic for Digital Input*

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3.3.2 Analog Inputs

Analog Inputs on Controller			
Pin	**Meaning**	**Pin**	**Meaning**
K1 - 10	+12V Out	**K1 - 22**	Analog Input 3
K1 - 11	Analog Input 1	**K1 - 23**	Analog Input 4
K1 - 12	I/O Ground	**K1 - 34**	Analog Input 5
K1 - 17	Analog Input 2	**K1 - 35**	+5V Out

Wiring

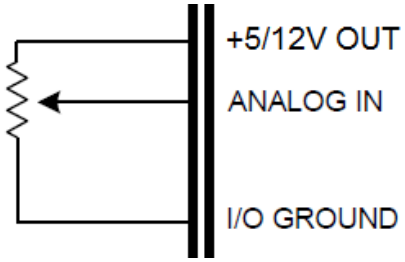

Figure 13 *- Potentiometer connected to Analog Input*

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3.3.3 Driver Outputs (PWM)

Driver Outputs on Controller			
Pin	**Meaning**	**Pin**	**Meaning**
K1 - 25	+12V Common	**K1 - 28**	Driver Output 3 (Max 2A)
K1 - 26	Driver Output 1 (Max 2A)	**K1 - 29**	Driver Output 4 (Max 2A)
K1 - 27	Driver Output 2 (Max 3A)		

Wiring

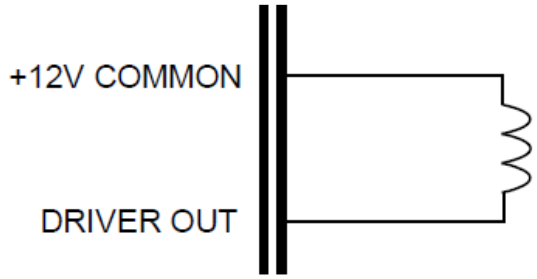

Figure 14 – *Driver Output Wiring*

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3.3.4 Digital Outputs (ON/OFF)

Digital Outputs on Controller			
Pin	**Meaning**	**Pin**	**Meaning**
K1 - 25	+12V Common	**K1 - 31**	Digital Output 2 (Max 2A)
K1 - 30	Digital Output 1 (Max 2A)		

Wiring

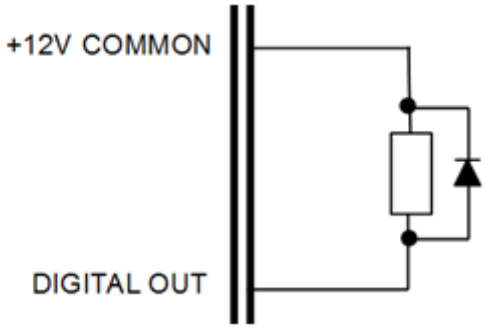

Figure 15 – *Digital Output Wiring*

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3.3.5 Speed/Position Sensor Inputs

Speed Sensor Inputs on Controller – ACIM Motors			
Pin	**Meaning**	**Pin**	**Meaning**
K1 - 9	I/O Ground	**K1 - 21**	Quad Encoder Channel A
K1 - 10	+12V Out	**K1 - 33**	Quad Encoder Channel B
		K1 - 35	+5V Out

Wiring

Quad Encoder Channels are 4V 470Ω Pull-up with $V_L \leq 1.5V$ and $V_H \geq 3.4V$.

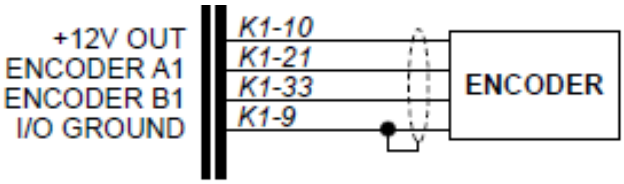

Figure 16a *- Quad Encoder Wiring*

Sin/Cos Encoder Analog Inputs Sin and Cos must be inside range 0,5V - 4,5V.

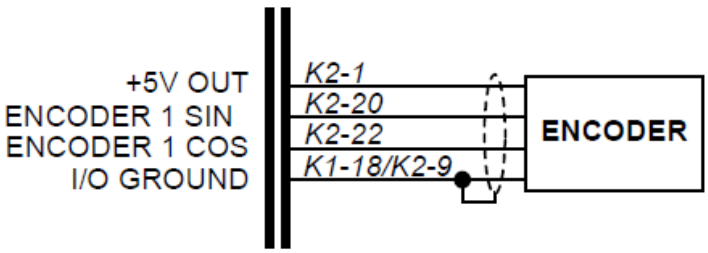

Figure 16b *- Sin/Cos Encoder Wiring*

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3.3.6 Thermal Probe

Thermal Probe Inputs on Controller			
Pin	**Meaning**	**Pin**	**Meaning**
K1 - 12	I/O Ground	**K1 - 32**	Motor Temperature Probe

Wiring

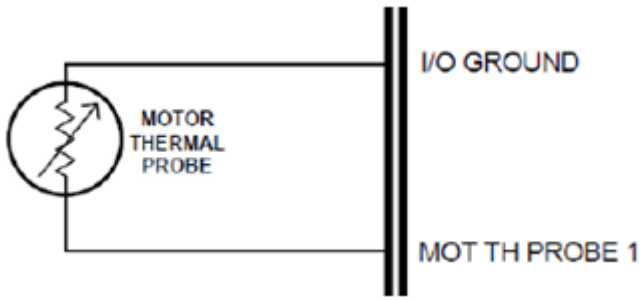

Figure 17 *- Thermal Probe Wiring*

The following sensors are supported:

Thermal Probe supported on Controller	
Code	**Meaning**
DKF103N3	NTC – Negative Temperature Coefficient
KTY84-130/150	PTC – Positive Temperature Coefficient
KTY83-121/122	PTC – Positive Temperature Coefficient
PT 1000	PTC – Positive Temperature Coefficient
SWITCH - (NO)	Normally Open Switch
SWITCH - (NC)	Normally Closed Switch

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3.3.7 Serial

Serial Pins on Controller			
Pin	**Meaning**	**Pin**	**Meaning**
K3 - 2	RS-232 RX	**K3 - 5**	I/O Ground
K3 - 3	RS-232 TX		

Wiring

The Controller communicates with the PC trough the serial **RS-232** with a speed of 38.4Kbps.

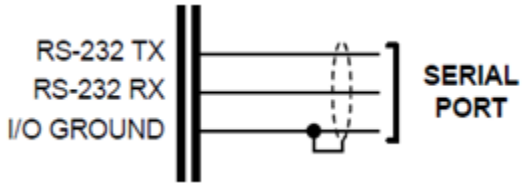

Figure 18 - *Serial Wiring*

You can communicate with the controller through:

- RS-232 serial port, using an interconnection cable.
- USB port, using a serial-to-USB converter:
  - Supported: Prolific chip
  - Recommended: **FTDI** chip

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3.3.8 CAN Network

Serial Pins on Controller			
Pin	**Meaning**	**Pin**	**Meaning**
K1 - 2	CAN - L	**K1 - 13**	CAN - H
K1 - 14	CAN - L RES	**K1 - 3**	CAN - H RES

Wiring

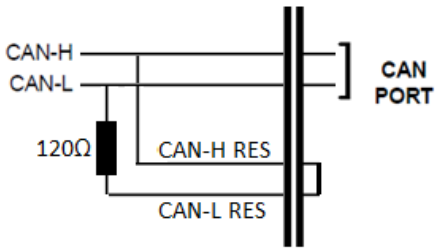
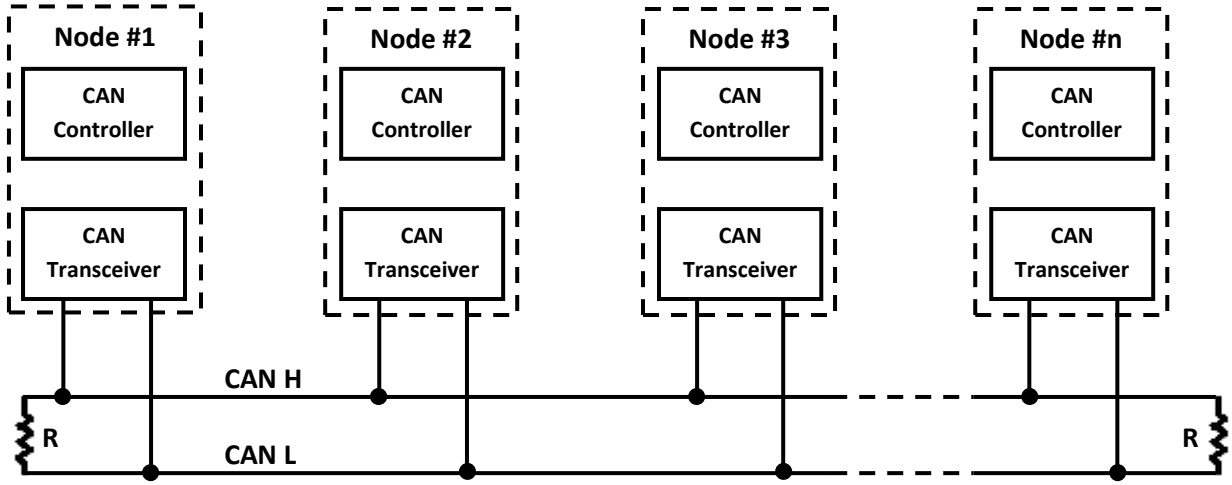


***Figure 19** - CAN Network Wiring*

The High-Speed ISO 11898 Standard specifications are given for a maximum signaling rate of 1 Mbps with a bus length of 40m and a maximum of 30 nodes. It also recommends a **maximum un-terminated stub length of 0.3m**. The cable is specified to be a shielded twisted-pair with a 120Ω characteristics impedance (Z_0). The Standard defines a single line of twisted-pair cable with the network topology as shown in the following picture:



It's terminated at both ends with 120Ω resistors in order to adapt the lines to a fixed impedance, avoiding reflections or other problems that can occur at high frequency of CAN (from 125KBaud to 1Mb). Placing these resistors on a node should be avoided since the bus line loses termination if the node is disconnected from the bus.

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4. Graphical Interface

The Controller has a number of parameters that can be calibrated using SME PC Graphical User Interface (GUI) which is user friendly and intuitive.

These programmable parameters allow the vehicle functions and performances to be customized to fit the needs of different applications. They are grouped into main categories (i.e. system, motor & control, traction / pump), and into additional subgroups, each with its own programming menu. Most of Controller default settings are fixed by SME software developers; even if user opt to leave most of the parameters at their default values, each parameter can be calibrated inside an allowable range.

Operator is easily guided through the process of parameter set-up and can communicate with the controller during working operations and can analyze real-time main system variables.

Do not drive the vehicle until initial set-up has been completed.

For deep and exhaustive information about programmable parameters and calibration procedure refer to the Interactive Documentation.

Minimum requirements

- 350MHz Pentium class or higher microprocessor
- 128MB or greater of RAM
- Serial port/USB port
- Graphic card 1MB
- Windows XP/Vista/7/8/8.1
- 1024x768 resolution video adapter

Recommended requirements

- 1GHz Pentium class or higher microprocessor
- 512MB of RAM
- Serial port/USB port
- Graphic card 2MB
- Windows XP/Vista/7/8/8.1
- 1024x768 resolution video adapter

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5. Diagnostic and troubleshooting

5.1 Overview

Diagnostic information about anomalous working condition is provided by using SME PC GUI or by SME display.

For deep and exhaustive information about the Faults detected by the Controller and the related Troubleshooting Guide, refer to the “Main Features” Area of the Interactive Documentation.

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6. EMC suggestions

6.1 General overview on EMC

Electromagnetic compatibility (EMC) encompasses two areas: emissions, i.e. the ability to work without causing electromagnetic disturbances to the nearing devices, and immunity, i.e. the ability to work in the presence of RF energy.

6.2 EM emissions

Signals with high frequency content can produce significant emissions if connected to a large enough radiating area (created by long wires spaced far apart). Also the contactor and motor drivers can emit significant disturbances, because their outputs are pulse width modulated square waves that are rich in harmonics (however, if a contactor supply is not modulated, its emission will be zero). The best way to minimize this kind of emission is to make as short as possible and place, if possible, each current near its return.

Controller:

- A good solution is to put the controller, wires, motors and the contactor in a shielded box, especially if very low emissions are required.
- For best noise immunity, the cables should not run across the section of the controller.

Battery:

- These two cables should be run close to each other between the Controller and the battery.
- With multiple high current controllers, use a star ground from the battery **B-** terminal.

Motor:

- The three phase wires should be close to the same length and bundled together as they run between the controller and the motor.
- In applications that seek the lowest possible emissions, a shield can be placed around the bundled motor cables and connected to the **B-** terminal at the controller. Typical installations will readily pass the emissions standards without a shield.

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6.3 Immunity to EM disturbances

Immunity is generally achieved by preventing the external electromagnetic disturbance from coupling into sensitive circuitry.

The wires connected to the controller act as antennas and the amount of RF energy coupled into them is proportional to their length.

Controller:

- The RF voltages and currents induced in each wire are applied to the controller pin to which the wire is connected. SME controllers include bypass capacitors on the printed circuit board's wires to reduce the impact of this source of noise on the internal circuitry, but in some applications an additional filtering in the form of ferrite beads might also be required.
- Radiated paths are created when the controller circuitry is immersed in an external field. This radiation may couple with the traces on the board and generate various kinds of malfunctions. If radiated disturbance is an issue, a good solution is to increase the distance between the controller and the possible sources of disturbance or to shield the controller by placing a metal enclosure around it.
- If a shield is required, holes should be added for ventilation purposes. In this case, using several small holes instead of few larger holes is preferable, because holes reduce the shielding capabilities (remember that reduction in shielding is a function of the longest linear dimension of a hole rather than the area).

Signal:

- Low current signal wires should not be run next to the motor cables. When necessary they should cross the motor cables at a right angle to minimize noise coupling.

Serial:

- Cut the black wire just over the cable's shield and solder it with the drain wire in both sides. Protect the soldering with the heat-shrink insulator.

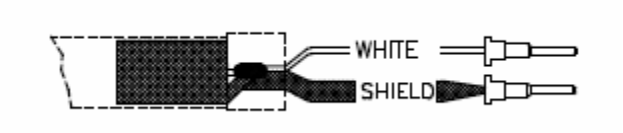

***Figure 19** – Shield connection*

CAN Wiring:

- CAN wiring should be kept away from the high current cables and cross it at right angles when necessary.
- It is strongly recommended to use twisted pair with shield and to connect it to ground.

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Appendix B: Document History

Rev. 1.0, March 2017:

First Release.

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