AC Asynchronous/Synchronous Motor Controller

USER MANUAL

(Rev. 1.0: March 2017)

SME S.p.A.
Via della Tecnica, n° 40
36071 Arzignano (VI) - ITALY
Phone:+39 (0444) 470511
Fax: +39 (0444) 451803
E-mail: sales@sme-group.com
www.sme-group.com

Model

AC-X1

Table of Contents

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

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.

SME group is able to offer a complete motion system for the different industrial lift truck ranges guaranteeing a high and safe performance customized to the client's requirements.

1.2 About this manual

This manual presents important information on configuring traction or pump systems using the *AC SmartMotion AC-X1* as well as details on sizing and selecting system components, options and accessories in an electrically powered vehicle.

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

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

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 *AC SmartMotion* 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)

Via della Tecnica, n°40

36071 Arzignano (VI), Italy

Phone:+39 (0444) 470511

Fax: +39 (0444) 451803

E-mail: sales@sme-group.com

support@sme-group.com

SME Shangai Co. Ltd (Asia)

No 2, Bldg. 8, 1st floor,

388, Xujing Shuanglian Road

201702 Qingpu District

Shanghai, China

Phone: +86 (021) 6025.3818

Fax: +86 (021) 59501502

E-mail: sales@sme-group.com

SME NA Inc (America)

1404 King St N, Box 154,

St Jacobs

Ontario, Canada

N0B 2N0

Phone: +1 (519) 591-0965

E-mail: sales@sme-group.com

SME S.p.A. Via della Tecnica 40 Z.I.

36071 ARZIGNANO (VI) ITALY

Phone +39 0444 470511 - Fax +39 0444 451803

sales@sme-group.com - www.sme-group.com

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.

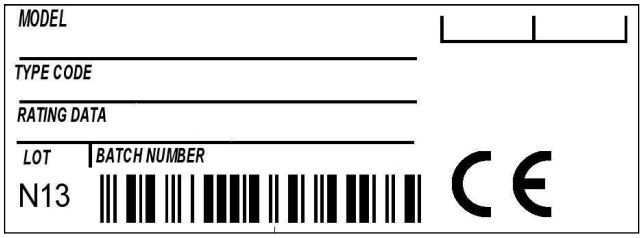
Being based on high reliable DCB technology and exceptionally stable Field Oriented Control (FOC) Algorithm, AC-X1 Controller is a revolutionary and high quality solution for medium power applications.

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

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

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

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

2.2 General Specifications

- **Motor Type:** AC Asynchronous/Synchronous 3-Phase
- **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 100V version		
Model Name	**AC Inverter Max Arms(2')**	**Max Power(2') at 100V**
AC-X1 100V 250A	250 A_{rms}	29.3kVA
AC-X1 100V 375A	375 A_{rms}	44.0kVA
AC-X1 100V 500A	500 A_{rms}	58.7kVA
AC-X1 100V 625A	625 A_{rms}	73.1kVA
AC-X1 100V 750A	750 A_{rms}	88.1kVA

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

2.3.2 Signal: Inputs and Outputs

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

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	GND	I/O Ground	Do not exceed 0.5A	Negative Logic Supply
2	CAN-L	CAN BUS	CAN-BUS 1 MBit/s max	CAN L (No internal termination resistor)
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 Resistor pull-down(active high) or pull up(active low) ON rated voltage +12V/24V	**TO BE ASSIGNED**
5	DIGITAL INPUT 2	Digital Input	VL<=2V,VH>=4.5V Resistor pull-down(active high) or pull up(active low) ON rated voltage +12V/24V	**TO BE ASSIGNED**
6	DIGITAL INPUT 3	Digital Input	VL<=2V,VH>=4.5V Resistor pull-down(active high) or pull up(active low) ON rated voltage +12V/24V	**TO BE ASSIGNED**
7	DIGITAL INPUT 4	Digital Input	VL<=2V,VH>=4.5V Resistor pull-down(active high) or pull up(active low) ON rated voltage +12V/24V	**TO BE ASSIGNED**
8	DIGITAL INPUT 5	Digital Input	VL<=2V,VH>=4.5V; resistor pull-down(active high) or pull up(active low) ON rated voltage +12V/24V	**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	12V Supply
11	ANALOG INPUT 1	Analog Input	0÷12V 125KΩ pull-down	**TO BE ASSIGNED**

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

K1 connector pin-out for AC-X1				SPECIFICATIONS
Pin	**Name**	**I/O**	**Specification**	**Typical Function**
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 (No internal termination resistor)
14	CAN-H RES	CAN BUS	Connected to CAN-H	Connected to CAN-H
15	LIN	Com Input/Output	19.2KBit/s 12V 1,1KΩ Pull-up RX: VL<=3.0V dominant, VH>=7.0V recessive	LIN Display Connection
16	DIGITAL IN 6	Digital Input	VL<=2V,VH>=4.5V Resistor pull-down(active high) or pull up(active low) ON rated voltage +12V/24V	**TO BE ASSIGNED**
17	ANALOG INPUT 2	Analog Input	0÷12V 125KΩ pull-down	**TO BE ASSIGNED**
18	DIGITAL IN 7	Digital Input	VL<=2V,VH>=4.5V Resistor pull-down(active high) or pull up(active low) ON rated voltage +12V/24V	**TO BE ASSIGNED**
19	DIGITAL IN 8	Digital Input	VL<=2V,VH>=4.5V Resistor pull-down(active high) or pull up(active low) ON rated voltage +12V/24V	**TO BE ASSIGNED**
20	DIGITAL IN 9	Digital Input	VL<=2V,VH>=4.5V Resistor pull-down(active high) or pull up(active low) ON rated voltage +12V/24V	**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**
23	ANALOG INPUT 4	Analog Input	0÷12V 125KΩ pull-down	**TO BE ASSIGNED**
24	KEY SWITCH IN	Supply Input	+ Battery supply: Max = Rated +20%, Min Batt = Rated -30%, Supply consumption: logic board 2A Max + coil return 8A max	Positive Supply of the control section of the AC-X1
25	COIL RETURN	Supply Output	(+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

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

K1 connector pin-out for AC-X1				SPECIFICATIONS
Pin	**Name**	**I/O**	**Specification**	**Typical Function**
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 No internal diode to coil return	Buzzer-Fan-ON/OFF valve
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	12V Supply

K3 connector pin-out for AC-X1				SPECIFICATIONS
Pin	**Name**	**I/O**	**Specification**	**Typical Function**
1	-	-	-	-
2	DIAGNOSTIC RX	Input	38.4-115.2 KBit/s, RS232 output compatible levels	Rx Diagnosis
3	DIAGNOSTIC TX	Output	38.4-115.2 KBit/s, RS232 output compatible levels	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	-

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

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)

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.

2.4 Operating Environment Specifications

- **Storage ambient temperature range:** -40°C ÷ +70°C
- **Operating ambient temperature range:** -40°C ÷ +55°C
- **Heatsink operating temperature range:** -40°C ÷ +95°C
    - ***With linear derating:*** +80°C ÷ +95°C
- **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

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

3. Installation and Wiring

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

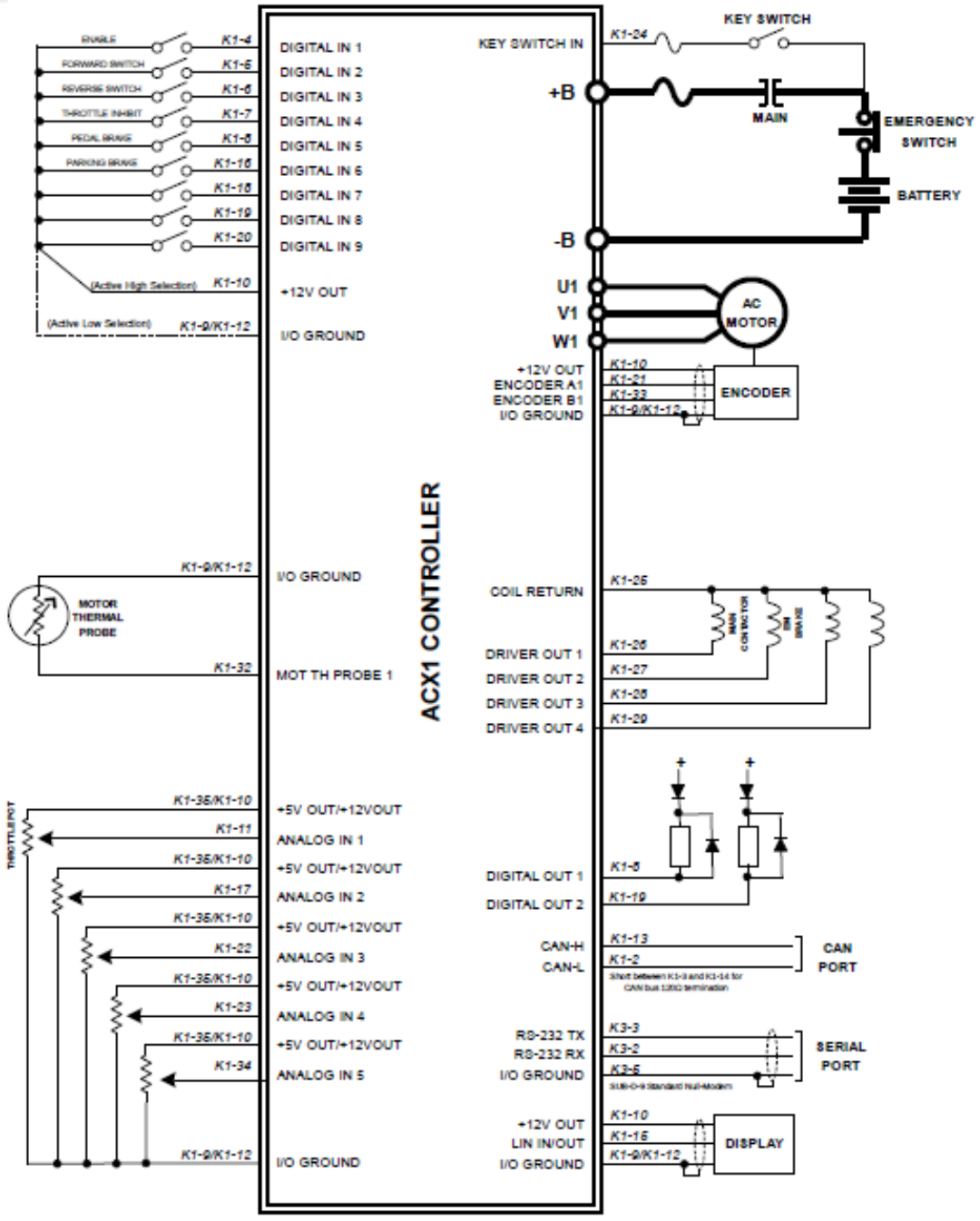


Figure 2a *- AC-X1 with Asynchronous Motor Wiring Diagram*

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

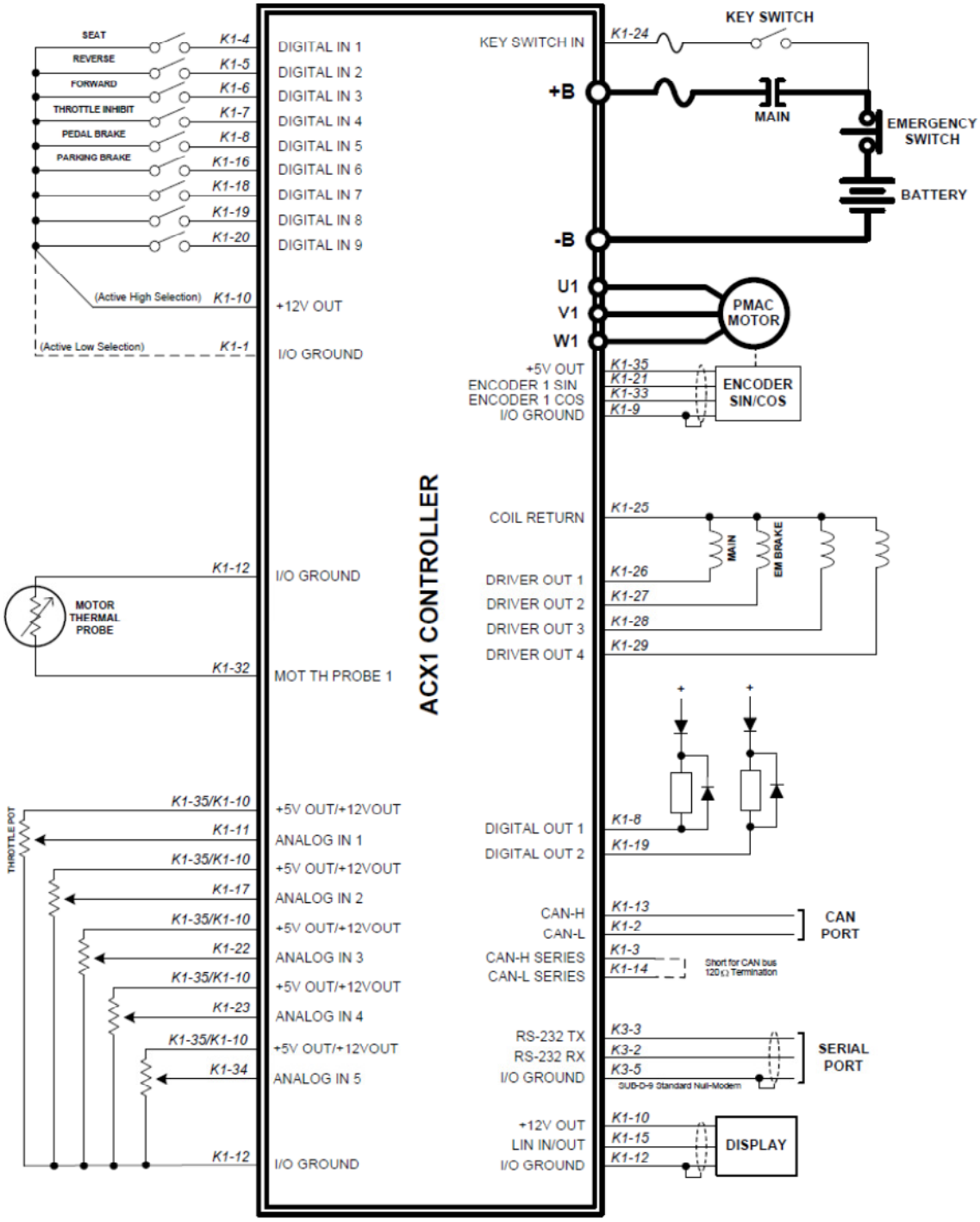


Figure 2b - *AC-X1 with Synchronous Motor Wiring Diagram*

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

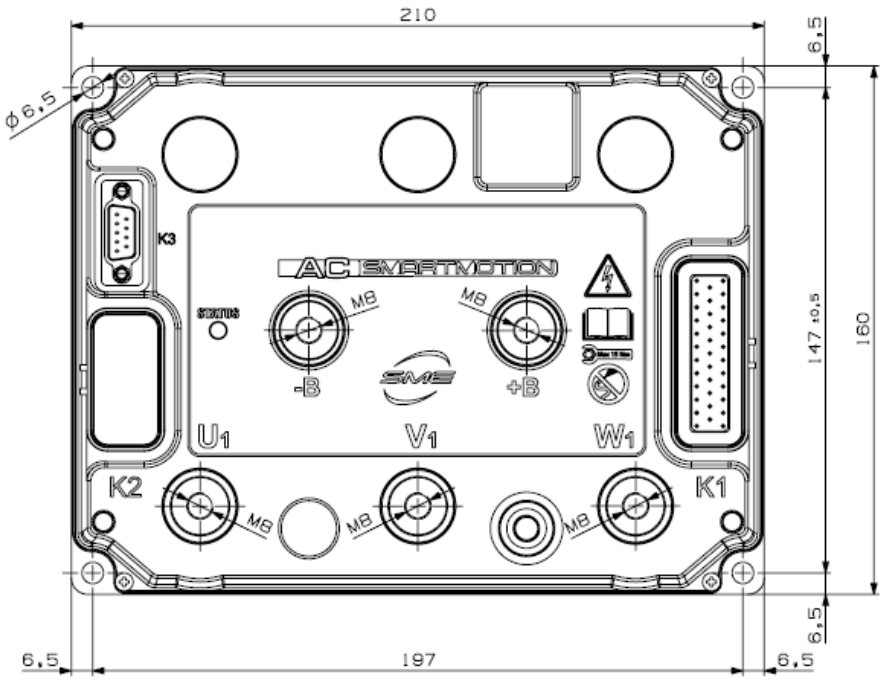
3.1 Controller

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

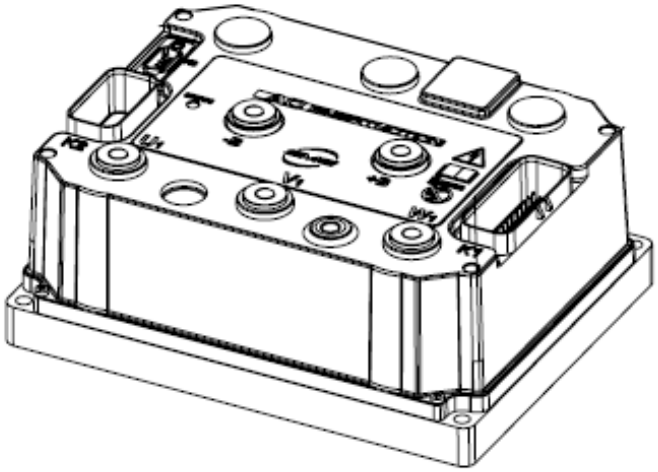
For high resolution diagram, refer to the About Controllers Area of the Interactive Documentation.



AC - X1 Top View

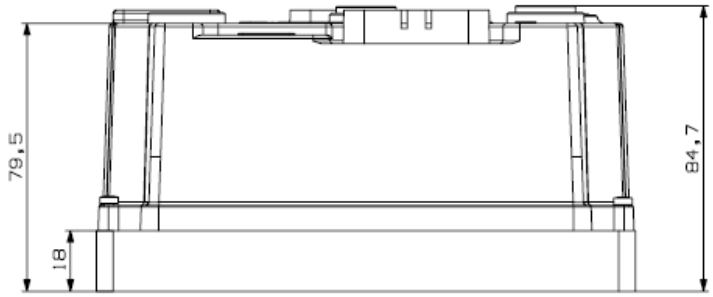
Figure 3 *– Top View*

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com



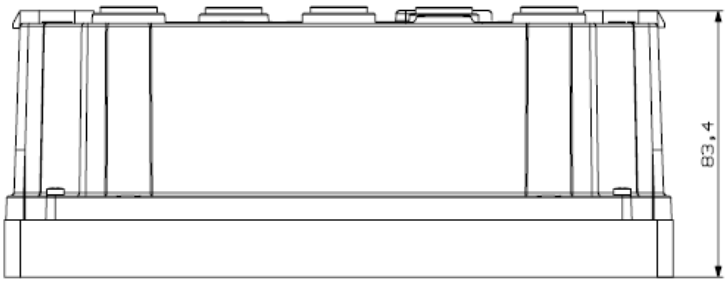
AC - X1 General View

Figure 3 *– General View*



AC - X1 Side View

Figure 4 *– Side View*



AC - X1 Back View

Figure 5 *- Back View*

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

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 across the inverter's +B and –B terminals.

Cooling

It is recommended that the Controller is assembled to a flat, free of paint surface preferably lightly coated with a thermal transfer compound using the 4 holes provided. Ideally, this surface will provide maximum heat dissipation and ensure full rated power output. When designing a cooling system, please refer to the following step:

1. Apply thermal grease to the Controller before mounting for better cooling effect.
2. The Controller is cooled by the surface contact to the vehicle body, so it is important to pay much attention to the flatness and the roughness of the surface of the vehicle frame where it is mounted. The roughness R_z should be between 1.6 µm and 3.2µm, while the planarity of the surface should be under 0.5mm, as shown in the following image:

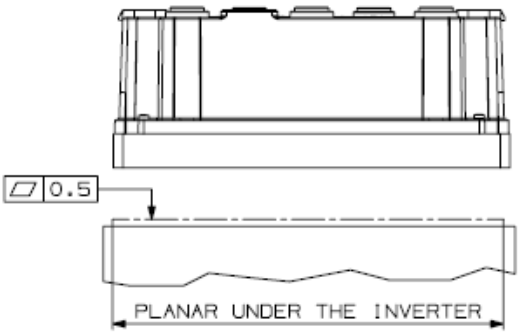


Figure 6 - Planarity

Planarity specifications for the AC-X1 with aluminium baseplate.

3. Any airflow around the controller will further enhance the thermal performance.

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

4. Additional heatsink could be necessary to meet the desired continuous ratings. The heat sink material and system should be sized on the performance requirement of the machine. We recommend ambient temperature air to be directed over the heatsink fins to maintain heatsink temperature below 75 °C.
5. In systems where either ventilation is poor, or heat exchange is difficult, forced air ventilation should be used.

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.

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

3.2 Power Terminals

Wiring

The Controller has five Power Terminals, which are clearly marked on Controller's body as **B+**, **B-**, **U**, **V**, **W** (figure 4).

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 6.5 Nm. This value is reported on the label placed on the cover, exceeding the recommended value may cause damages.

Sizing

The environment conditions strongly affect the current carrying capacity of a single wire. Temperature and wire length can decrease the cable performance and other factors such as Controller duty cycles and airflow should also be taken into consideration when sizing the power cables.

The following formula gives an advice on the cable size needed in welding cable, not grouped with other cables:

$$Minimum\ Wire\ Section\ suggested[mm^2] = \frac{Average\ Current}{Suggested\ Current\ Density}$$

- **Ambient Temperature = 25°C**
- **Maximum Temperature rise on the cable surface = 60°C**
- **Suggested Current Density [A_{rms}/mm^2] = 5 A_{rms}/mm^2**

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

The following table shows you the most common cases:

Standard Wire Dimensions			
Average Current [Arms]	**Minimum Wire Section Suggested [mm^2]**	**Wire Size**	
		mm^2	**AWG**
100	20	21.1	4
150	30	33.6	2
200	40	42.4	1
250	50	53.5	0
300	60	67.4	2/0
350	70	85	3/0

3.3 Main Contactor

The Controller must be connected to one Main Contactor for two basically reasons:

- **Capacitors Pre-Charge** : The Controller handles all this phase internally by discharging/charging its DC-Bus through the Key Input. As soon as a certain voltage value is reached by the DC-Bus, the Controller can close the Main Contactor connecting it to the Battery. In this way dangerous shocks on Controller's capacitors are avoided.
- **Safety**: In case of dangerous situations, the Main Contactor must be opened disconnecting the Battery from Controller. **If the main contactor coil is not connected to the controller, the system will not meet EEC safety requirements.**

Sizing

In order to select the Main Contactor, it must be considered the Controller Ratings, the Duty Cycle of the System and several other working conditions. The following empirical formula can be useful to quickly find the **Main Contactor minimum rating I_{MC}**:

$$I_{MC} = \frac{Max\ Power\ 2'[kVA] \times 1000 \times 0.6}{V_{Battery}}$$

with $0.6 =$ Factor between Maximum (S2 2′)and Continous Power(S2 60′)

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

3.4 Fuse

A fuse protects the Controller and the entire system against **shorts circuit in the power section** and it can be mounted in the Controller between the +B and the related terminal.

Anyway, consider that the fuse doesn't be used to avoid overloads on the Controller or on the AC Motor. The firmware inside the Controller already manages them so they don't usually cause the fuse to blow.

Sizing

In order to select the Fuse Rating, refer to the following formula:

$$I_{FUSE} = \frac{Max\ Power\ 2'[kVA] \times 1000 \times \overline{\cos(\varphi)}}{V_{Battery} \times \mu_C}$$

with μ_C = Minimum Controller Efficency = 0.95 and $\overline{\cos(\varphi)}$ = Medium Power Factor

You must choose a fuse with specific rating and time delay characteristics.

It must carry I_{FUSE} indefinitely, but blow within maximum 3 seconds for 2 x I_{FUSE} .

The following diagram shows common dimensions for fuse on Controller.

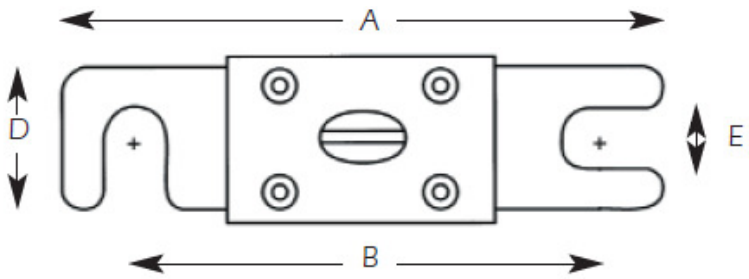


Figure 7 – *Fuse Dimensions*

	Dimensions[mm]
A	82
B	60
D	20
E	11

Suggested Manufacturers are FERRAZ, BUSSMAN, LITTELFUSE and others which satisfy the time delay and dimensions required.

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

3.5 Signal

The Controller uses:

- Two Ampseal connectors:

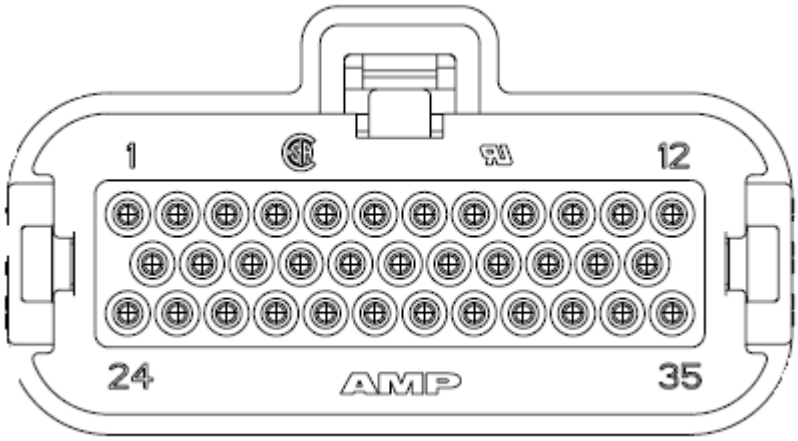


Figure 9 *- Ampseal Connector K1*

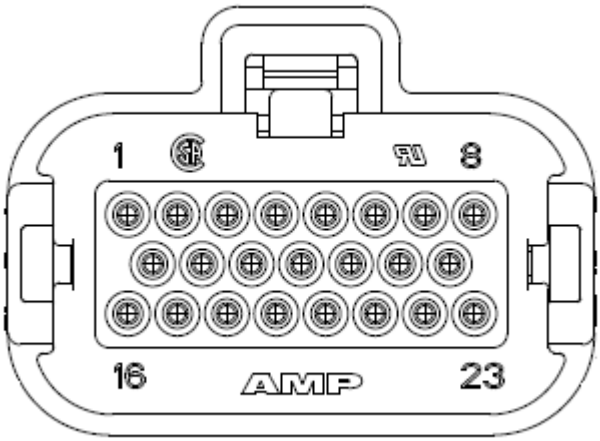


Figure 10 *- Ampseal Connector K2*

Refer to the following specifications for these connectors:

- **Number of Positions:** 35 and 23 Positions
- **Mounting Style:** Wire
- **Termination Style:** Crimp
- **Contact Type:** Plug
- **Current Rating:** 17 A
- **Housing Material:** Thermoplastic

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

- **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**.

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:

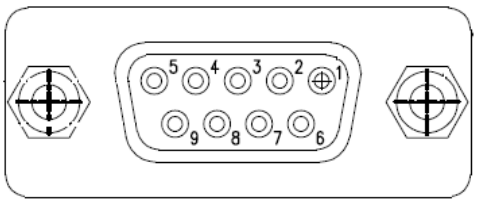


Figure 11 - *SUB-D Connectors K3*

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

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

3.5.1 Digital Inputs

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

Wiring

All Digital Inputs are made with internal resistor pull-down(active high) or pull up(active low). The ON rated voltage is +12V/24V.

All of them have $V_L \leq 2V$ and $V_H \geq 4.5V$.

Active High Selection

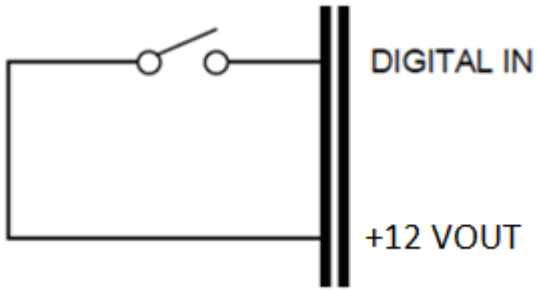


Figure 11 - *Positive Logic for Digital Input*

Active Low Selection

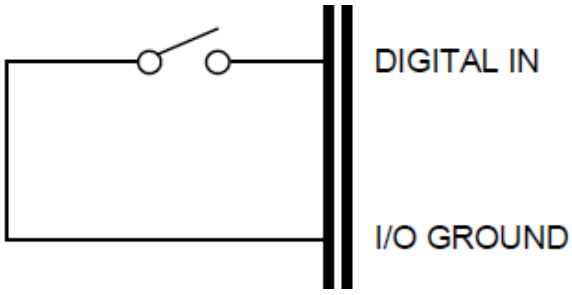


Figure 12 - *Negative Logic for Digital Input*

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

3.5.2 Analog Inputs

Analog Inputs on Controller			
Pin	**Meaning**	**Pin**	**Meaning**
K1 - 9	I/O Ground	**K1 - 22**	Analog Input 3
K1 - 10	+12V Out	**K1 - 23**	Analog Input 4
K1 - 11	Analog Input 1	**K1 - 34**	Analog Input 5
K1 - 12	I/O Ground	**K1 - 35**	+5V Out
K1 - 17	Analog Input 2		

Wiring

All Analog Inputs are 0÷12V pull down, with an internal impedance equal to 125KΩ.

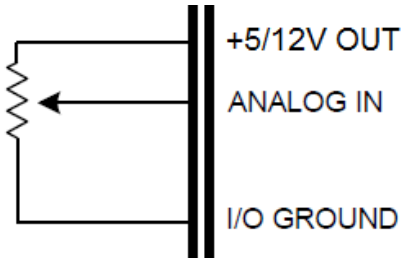


Figure 8 *- Potentiometer connected to Analog Input*

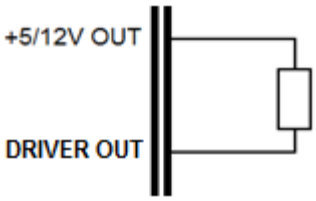
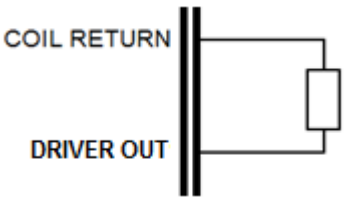
SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

3.5.3 Driver Outputs (PWM)

Driver Outputs on Controller			
Pin	**Meaning**	**Pin**	**Meaning**
K1 - 10	+12V Out	**K1 - 28**	Driver Output 3 (Max 2A)
K1 - 25	Coil Return	**K1 - 29**	Driver Output 4 (Max 2A)
K1 - 26	Driver Output 1 (Max 2A)	**K1 - 35**	+5V Out
K1 - 27	Driver Output 2 (Max 3A)		

Wiring

The Driver Output (low side output) is the negative reference applied to the load. The positive reference is given by the other pin connected:

Driver Outputs Wiring on Controller	
Positive Reference	**How to wire**
Controller +5/12V	
Battery Voltage	

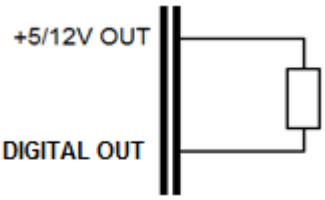
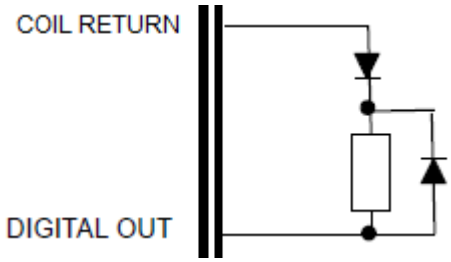
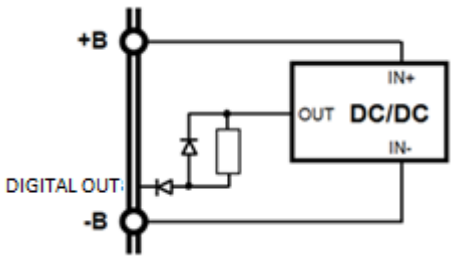
SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

3.5.4 Digital Outputs (ON/OFF)

Digital Outputs on Controller			
Pin	**Meaning**	**Pin**	**Meaning**
K1 - 10	+12V Out	**K1 - 31**	Digital Output 2 (Max 2A)
K1 - 25	Coil Return	**K1 - 35**	+5V Out
K1 - 30	Digital Output 1 (Max 2A)		

Wiring

The Digital Output (low side output) is the negative reference applied to the load. The positive reference is given by the other pin connected:

Digital Outputs Wiring on Controller	
Positive Reference	**How to wire**
Controller +5/12V	
Battery Voltage	
External Supply from a DC/DC converter	

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

3.5.5 Speed/Position Sensor Inputs

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

Wiring

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

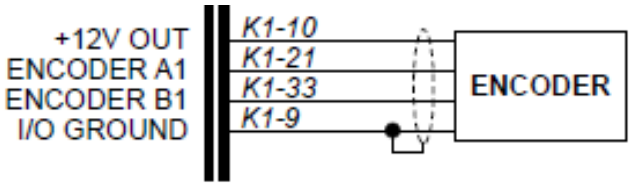


Figure 9a *- Quad Encoder Wiring*

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

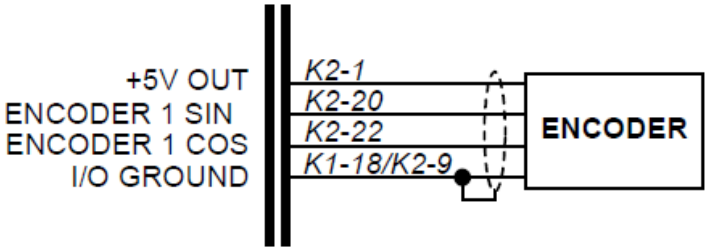


Figure 10b *- Sin/Cos Encoder Wiring*

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

3.5.6 Thermal Probe

Thermal Probe Inputs on Controller			
Pin	**Meaning**	**Pin**	**Meaning**
K1 - 9	I/O Ground	**K1 - 32**	Motor Temperature Probe
K1 - 12	I/O Ground		

Wiring

The Controller can acquire the Motor Temperature through the Thermal Sensor:

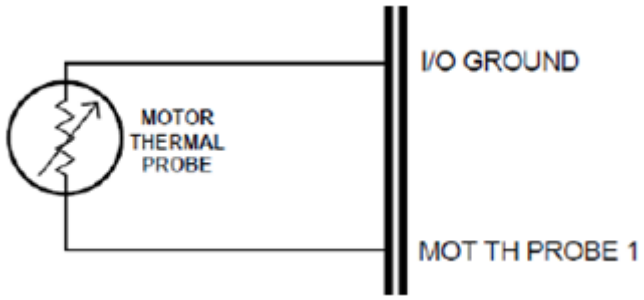


Figure 11 *- Thermal Probe Wiring*

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

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

3.5.7 Serial

Serial Pins on Controller			
Pin	**Meaning**	**Pin**	**Meaning**
K3 - 2	RS-232 RX	**K3 - 5**	I/O Ground
K3 – 3	RS-232 TX	**K3 - 9**	+5V Out

Wiring

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

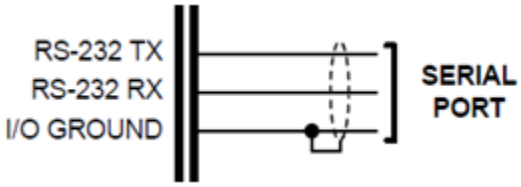


Figure 12 - *Serial Wiring*

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

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

3.5.8 CAN Network

Serial Pins on Controller			
Pin	**Meaning**	**Pin**	**Meaning**
K3 - 2	CAN - L	**K3 - 3**	CAN - H
K3 - 3	CAN - L RES	**K3 - 9**	CAN - H RES

Wiring

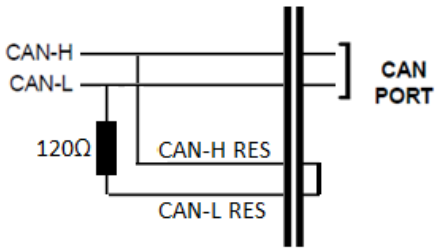
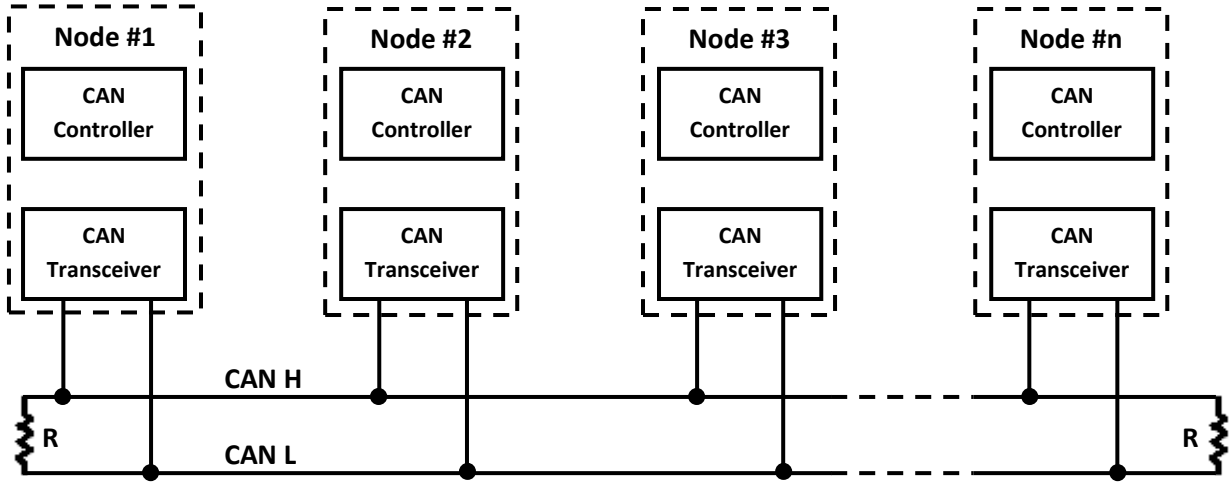


***Figure 136** - CAN Network Wiring*

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.

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

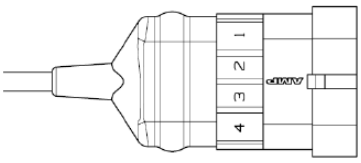
3.6 SME external devices description

The Controller can be connected to SME external devices described below.

3.6.1 Quad Encoder

Quad encoder can detect the rotating motion of the toothed wheel fixed to the motor shaft and it generates two electrical signals (square wave and open collector type), usual for kind of encoders. The two output signals, named channel A and channel B, are shifted by 90 electrical degrees. Their frequency is proportional to the rotational speed of the motor shaft. Since the toothed wheel has 64 teeth, each channel generates 64 pulses every complete turn of the shaft.

SME Quad Encoder			
Electrical Data		**Mechanical Data**	
Pulses/Rev	64	**Protection Level**	IP67
Max. Speed	10000rpm	**Weight**	64g

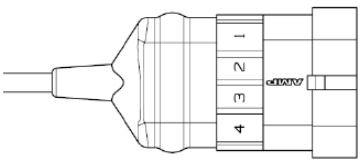


Pin	Wiring
1	Vcc
2	Gnd
3	Channel A
4	Channel B

3.6.2 Sin/Cos Encoder

Sin/Cos encoder is composed of a magnetic actuator that must be mounted on the motor shaft and a sensor board. Rotation of the actuator is sensed by the encoder board, and processed to give for output sine and cosine waveforms.

SME Sin/Cos Encoder			
Electrical Data		**Mechanical Data**	
Periods/Rev	1	**Protection Level**	-
Max. Speed	-	**Weight**	-



Pin	Wiring
-	Vcc
-	Gnd
-	Sin
-	Cos

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

3.6.3 Displays

SME displays (Compact or Mini) are optional devices which show overall information about your system. They have to be connected to controller through LIN interface.

Figure 14 - *Display Compact*

Figure 15 - *Display Mini*

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.

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

Minimum requirements

- 350MHz Pentium class or higher microprocessor
- 128MB or greater of RAM
- Serial port/USB port
- Graphic card 1MB
- Windows XP/Vista/7/8/10/11
- 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/7/8/8.1/10/11
- 1024x768 resolution video adapter

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.

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

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.

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

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:

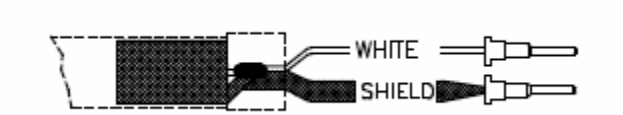
- The RF voltages and currents induced in each wire are applied to the controller pin to which the wire is connected. SME controllers include bypass capacitors on the printed circuit board's wires to reduce the impact of this source of noise on the internal circuitry, but in some applications an additional 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.



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.

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com

Appendix B: Document History

Rev. 1.0, March 2017:

Initial version.

SME S.p.A. Via della Tecnica 40 Z.I.
36071 ARZIGNANO (VI) ITALY
Phone +39 0444 470511 - Fax +39 0444 451803
sales@sme-group.com - www.sme-group.com