



AC Induction Motor Controller

USER MANUAL

(Rev. 3.0: March 2016)



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

Model

AC-M1

Table of Contents

Table of Contents	2
1. Introduction	4
1.1 About SME Company	4
1.2 About this manual.....	4
1.3 About warning, caution and information notices.....	4
1.4 Product warranty information	5
1.5 How to find us	5
2. AC SmartMotion AC-M1 Overview	6
2.1 Product description.....	6
2.1.1 Product Indication Label.....	7
2.2 General Specifications.....	8
2.3 Electrical Specifications.....	8
2.3.1 Input and Output Ratings	8
2.3.2 Signal: Inputs and Outputs.....	9
2.3.3 Interfaces	11
2.3.4 EMC.....	11
2.3.5 Safety	11
2.4 Operating Environment Specifications	11
3. Installation and Wiring.....	12
3.1 Controller	13
3.2 Power Terminals	17
3.3 Main Contactor	18
3.4 Fuse	19
3.5 Signal	20
3.5.1 Digital Inputs.....	21

3.5.2	Analog Inputs	22
3.5.3	Driver Outputs (PWM)	23
3.5.4	Digital Outputs (ON/OFF).....	24
3.5.5	Speed Sensor Inputs	25
3.5.6	Thermal Probe	26
3.5.7	Serial	27
3.5.8	CAN Network	28
3.6	SME external devices description	29
3.6.1	Encoder	29
3.6.2	Displays	29
4.	Graphical Interface	30
5.	Diagnostic and troubleshooting.....	31
5.1	Overview	31
6.	EMC suggestions	32
6.1	General overview on EMC.....	32
6.2	EM emissions	32
6.3	Immunity to EM disturbances.....	33
	Appendix B: Document History	34

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-M1* 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.



User Manual Reference. A User Manual Reference informs the user to look up specified user manual for more details.



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

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 S.p.A. (Europe - Headquarters)

Via della Tecnica, n°40
36071 Arzignano (VI), Italy

Phone: +39 (0444) 470511

Fax: +39 (0444) 451803

E-mail: info@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: info@sme-group.com

SME Drives Inc (America)

1404 King St N, Box 154,
St Jacobs
Ontario, Canada
NOB 2N0

Phone: +1 (519) 591-0965

E-mail: info@sme-drives.com

2. AC SmartMotion AC-M1 Overview



Figure 1 - AC-M1

2.1 Product description


The AC-M1 Controller is designed to control AC motors.

Being based on high reliable DCB technology and exceptionally stable ITC Control Algorithm, AC-M1 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.

2.1.1 Product Indication Label

The product label shows important data regarding the specific product.

MODEL			
TYPE CODE			
RATING DATA			
LOT	BATCH NUMBER		
N13		 	

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

2.2 General Specifications

- **Motor Type:** AC Asynchronous 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 24V version		
Model Name	AC Inverter Max Arms(2')	Max Power(2') at 24V
AC-M1 24V 350A	350 A _{rms}	9.7kVA
AC-M1 24V 450A	450 A _{rms}	12.5 kVA

Model Chart for 36/48V version		
Model Name	AC Inverter Max Arms(2')	Max Power (2') at 48V
AC-M1 36/48V 375A	375 A _{rms}	20.8 kVA
AC-M1 36/48V 500A	500 A _{rms}	27.5 kVA

Model Chart for 72/80V version		
Model Name	AC Inverter Max Arms(2')	Max Power (2') at 80V
AC-M1 72/80V 350A	350 A _{rms}	32.3 kVA
AC-M1 72/80V 450A	450 A _{rms}	41.6 kVA

2.3.2 Signal: Inputs and Outputs

- **Digital Inputs:** 19
- **Analog Inputs:** 6
- **Digital Outputs (ON/OFF):** 2
- **Driver Outputs (PWM):** 3
- **Motor Speed Sensor Inputs:** 2 (A+B Channels)

Refer to following tables for a complete AC-M1 controller K1 and K2 connectors pin-out.

K1 connector pin-out for AC-M1				SPECIFICATIONS
Pin	Name	I/O	Specification	Typical Function
1	KEY SWITCH IN	Supply Input	Rated battery +25/-30%, 6Amax	Positive supply of the control section of the AC-M1
2	DIGITAL IN 1	Digital Input	4mA pull-up, VL<=1V, VH>=3,5V	TO BE ASSIGNED
3	DIGITAL IN 2	Digital Input	4mA pull-up, VL<=1V, VH>=3,5V	TO BE ASSIGNED
4	DIGITAL IN 3	Digital Input	4mA pull-up, VL<=1V, VH>=3,5V	TO BE ASSIGNED
5	DIGITAL IN 4	Digital Input	4mA pull-up, VL<=1V, VH>=3,5V	TO BE ASSIGNED
6	DIGITAL IN 5	Digital Input	4mA pull-up, VL<=1V, VH>=3,5V	TO BE ASSIGNED
7	DIGITAL IN 6	Digital Input	4mA pull-up, VL<=1V, VH>=3,5V	TO BE ASSIGNED
8	DIGITAL OUT 1	Digital Output	Low side 0,5A	TO BE ASSIGNED
9	COIL RETURN	Supply Output	High side 5A max	Positive common
10	RS-232 RX	Com Input	-	Serial port
11	RS-232 TX	Com Output	-	Serial port
12	DIGITAL IN 7	Digital Input	4mA pull-up, VL<=1V, VH>=3,5V	TO BE ASSIGNED
13	DIGITAL IN 8	Digital Input	4mA pull-up, VL<=1V, VH>=3,5V	TO BE ASSIGNED
14	LIN IN/OUT	Com Input/Output	12mA pull-up	LIN display connection
15	CAN-H	Com Input/Output	CAN-bus	CAN H (No internal termination resistor)
16	DRIVER OUT 1	PWM Output	Low side 2A	TO BE ASSIGNED
17	DRIVER OUT 2	PWM Output	Low side 1,5A	TO BE ASSIGNED
18	I/O GROUND	-	-	Negative logic supply
19	DIGITAL OUT 2	Digital Output	Low side 1,5A	TO BE ASSIGNED
20	DRIVER OUT 3	PWM Output	Low side 1,5A (*)	TO BE ASSIGNED
21	+12V OUT	Supply Output	12V 300mAmx	12V supply
22	CAN GROUND	-	-	CAN- bus negative supply
23	CAN-L	Com Input/Output	CAN-bus	CAN L (No internal termination resistor)

K2 connector pin-out for AC-M1				SPECIFICATIONS
Pin	Name	I/O	Specification	Function
1	+5V OUT	Supply Output	5V+/-5%, 200mAmax	5V supply
2	DIGITAL IN 9	Digital Input	20mA pull-up, VL<=1V, VH>=3,5V	TO BE ASSIGNED
3	DIGITAL IN 10	Digital Input	20mA pull-up, VL<=1V, VH>=3,5V	TO BE ASSIGNED
4	ENCODER 1 B	Peripheral Input	20mA pull-up, VL<=1V, VH>=3,5V	Quad encoder channel B
5	ENCODER 1 A	Peripheral Input	20mA pull-up, VL<=1V, VH>=3,5V	Quad encoder channel A
6	DIGITAL IN 11	Digital Input	4mA pull-up, VL<=1V, VH>=3,5V	TO BE ASSIGNED
7	DIGITAL IN 12	Digital Input	4mA pull-up, VL<=1V, VH>=3,5V	TO BE ASSIGNED
8	DIGITAL IN 13	Digital Input	4mA pull-up, VL<=1V, VH>=3,5V	TO BE ASSIGNED
9	I/O GROUND	-	-	Negative logic supply
10	MOTOR THERMAL PROBE 1	Analog Input	Pull-up	Motor temperature probe
11	MOTOR THERMAL PROBE 2	Analog Input	Pull-up	TO BE ASSIGNED
12	ANALOG IN 1	Analog Input	0/12V pull-down	TO BE ASSIGNED
13	ANALOG IN 2	Analog Input	0/12V pull-down	TO BE ASSIGNED
14	DIGITAL IN 14	Digital Input	4mA pull-up, VL<=1V, VH>=3,5V	TO BE ASSIGNED
15	DIGITAL IN 15	Digital Input	4mA pull-up, VL<=1V, VH>=3,5V	TO BE ASSIGNED
16	DIGITAL IN 16	Digital Input	4mA pull-up, VL<=1V, VH>=3,5V	TO BE ASSIGNED
17	DIGITAL IN 17	Digital Input	4mA pull-up, VL<=1V, VH>=3,5V	TO BE ASSIGNED
18	DIGITAL IN 18	Digital Input	4mA pull-up, VL<=1V, VH>=3,5V	TO BE ASSIGNED
19	ANALOG IN 3	Analog Input	0/12V pull-down	TO BE ASSIGNED
20	ANALOG IN 4	Analog Input	0/12V pull-down	TO BE ASSIGNED
21	ANALOG IN 5	Analog Input	0/12V pull-down	TO BE ASSIGNED
22	ANALOG IN 6	Analog Input	0/12V pull-down	TO BE ASSIGNED
23	DIGITAL IN 19	Digital Input	4mA pull-up, VL<=1V, VH>=3,5V	TO BE ASSIGNED

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:** $-40^{\circ}\text{C} \div +70^{\circ}\text{C}$
- **Operating ambient temperature range:** $-40^{\circ}\text{C} \div +55^{\circ}\text{C}$
- **Heatsink operating temperature range:** $-40^{\circ}\text{C} \div +95^{\circ}\text{C}$
 - *With linear derating:* $+80^{\circ}\text{C} \div +95^{\circ}\text{C}$
- **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 145 x 91 [mm]
- **Weight:** 3 kg

3. Installation and Wiring



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

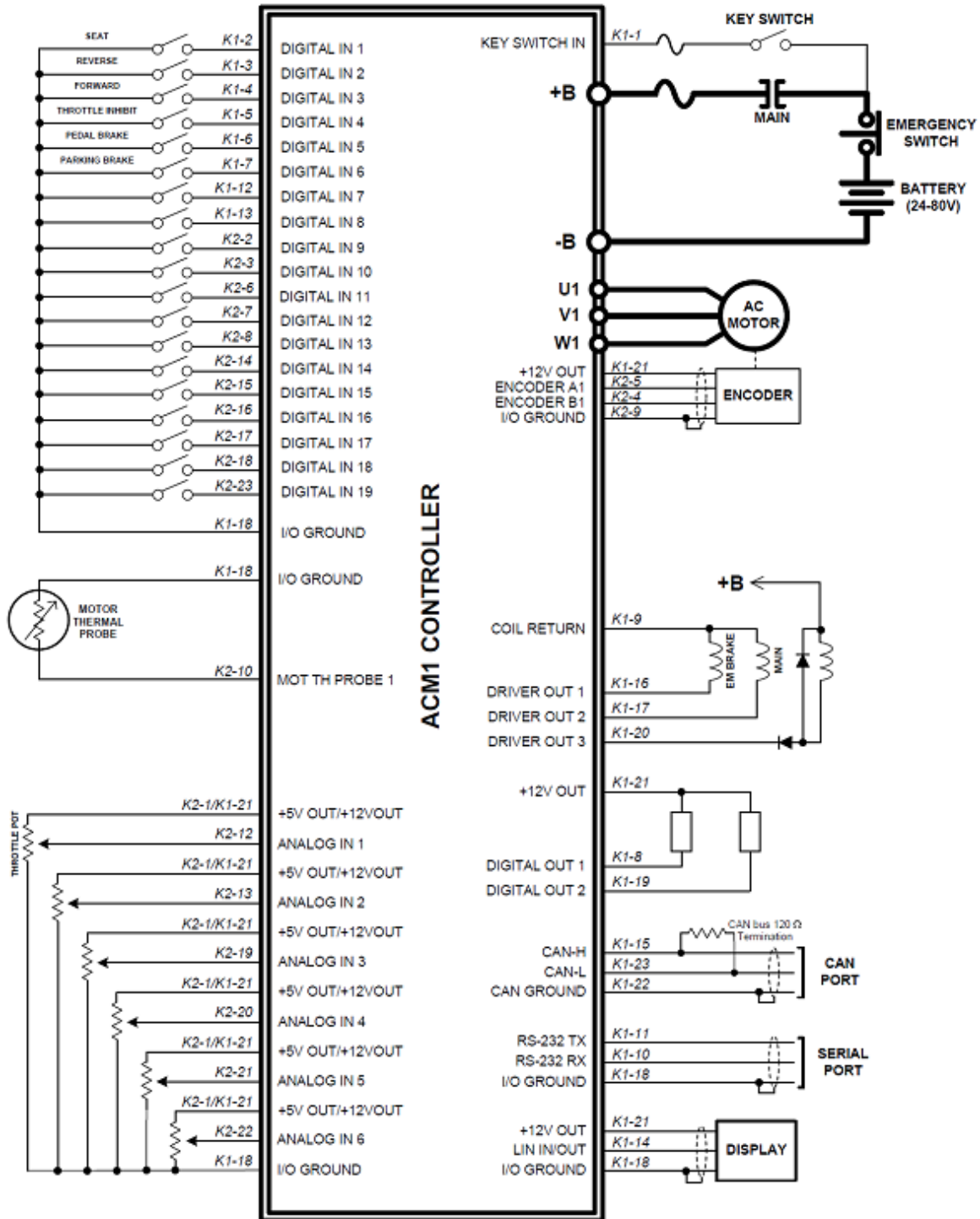


Figure 2 - AC-M1 Wiring Diagram

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.

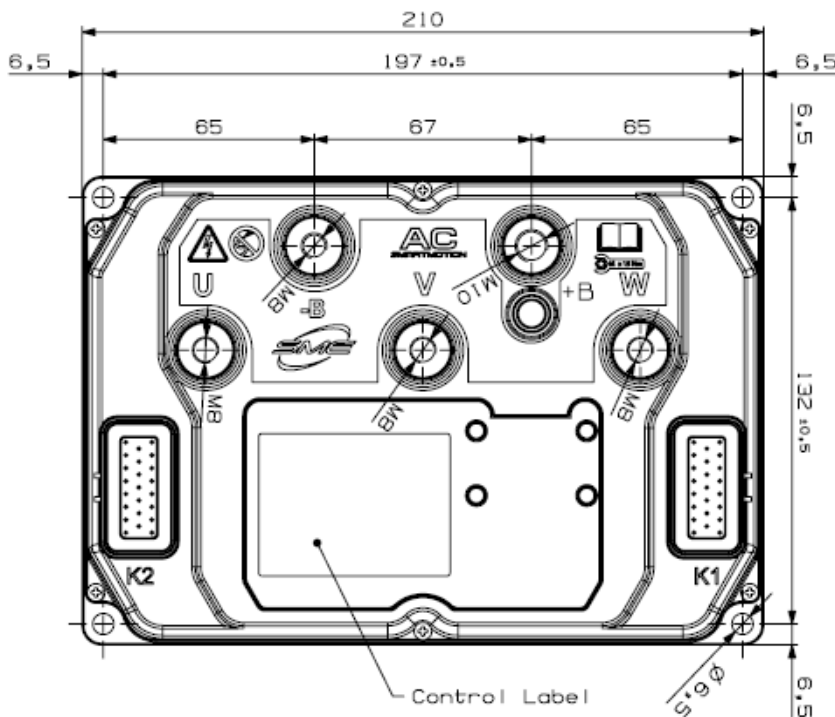
Never energize the system if the terminals –B and +B are not tightly connected.

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

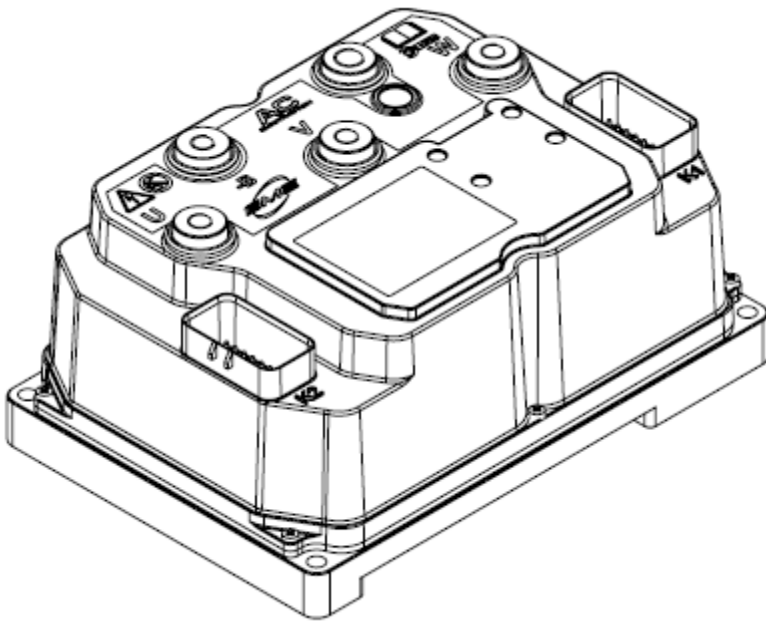


For high resolution diagram, refer to the About Controllers Area of the Interactive Documentation.



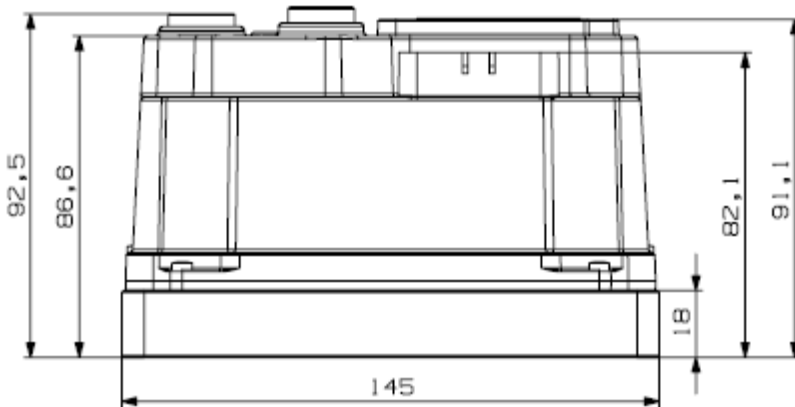
AC - M1 Top View

Figure 3 – Top View



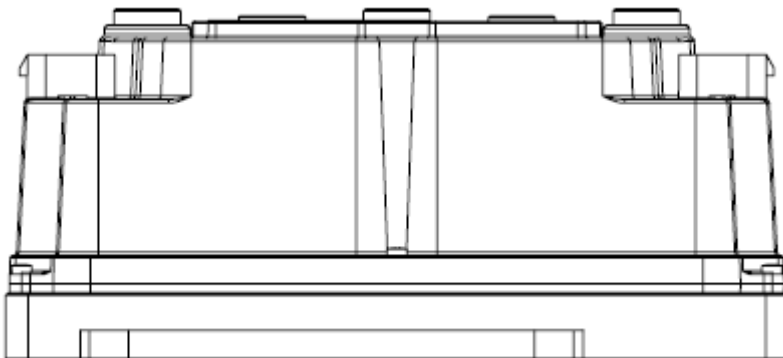
AC - M1 General View

Figure 4 – General View



AC - M1 Side View

Figure 5 – Side View



AC - M1 Back View

Figure 6 - Back View

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.



Avoid to swap K1 and K2 connectors. This operation can seriously damage the Controller

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 $1.6 \mu\text{m}$ and $3.2 \mu\text{m}$, while the planarity of the surface should be under 0.5mm , as shown in the following image:

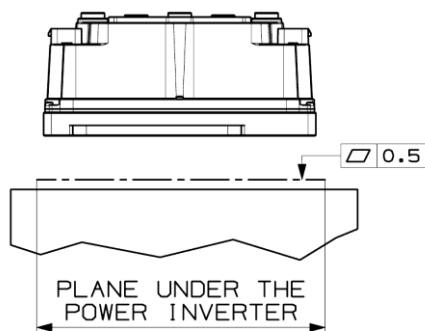


Figure 7 - Planarity

Planarity specifications for the AC-M1 with aluminium baseplate.

3. Any airflow around the controller will further enhance the thermal performance.
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-M1 models 50 mm clearances in front of and behind the AC-M1 are required for airflow; 50 mm clearance above the AC-M1 is required for installation/removal of interface connectors and wiring.

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 6.4 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:

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

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

The following table shows you the most common cases:

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 Continuous Power (S2 60')

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 Efficiency = 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 $2 \times I_{FUSE}$.

The following diagram shows common dimensions for fuse on Controller.

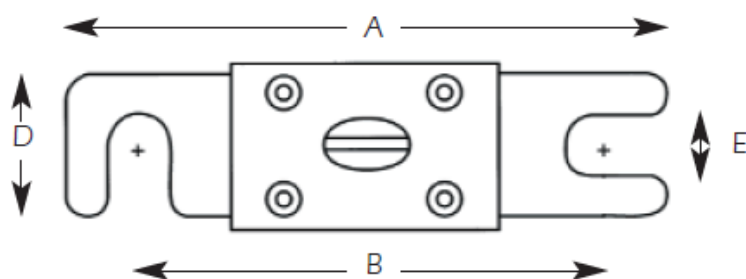


Figure 8 – Fuse Dimensions

	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.

3.5 Signal

The Controller uses two Ampseal connectors:

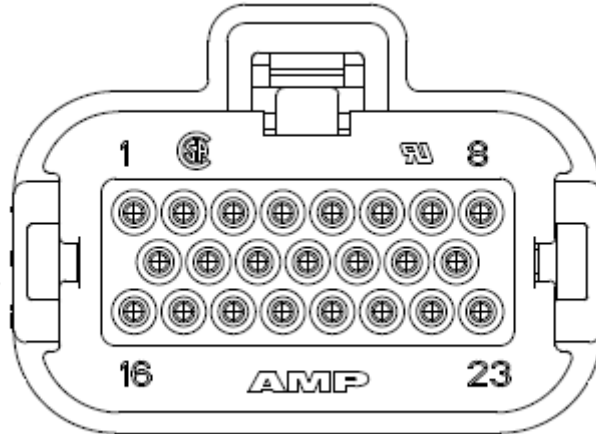


Figure 9 - Ampseal Connector

Refer to the following specifications for these connectors:

- **Number of Positions:** 23 Position
- **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**.

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

3.5.1 Digital Inputs

Digital Inputs on Controller			
Pin	Meaning	Pin	Meaning
K1 - 2	Digital Input 1	K2 - 2	Digital Input 9
K1 - 3	Digital Input 2	K2 - 3	Digital Input 10
K1 - 4	Digital Input 3	K2 - 6	Digital Input 11
K1 - 5	Digital Input 4	K2 - 7	Digital Input 12
K1 - 6	Digital Input 5	K2 - 8	Digital Input 13
K1 - 7	Digital Input 6	K2 - 14	Digital Input 14
K1 - 12	Digital Input 7	K2 - 15	Digital Input 15
K1 - 13	Digital Input 8	K2 - 16	Digital Input 16
K1 - 18	I/O Ground	K2 - 17	Digital Input 17
		K2 - 18	Digital Input 18
		K2 - 23	Digital Input 19

Wiring

All Digital Inputs are 4mA pull-up except K2-2 and K2-3 which are 20mA pull-up.

All of them have $V_L \leq 1V$ and $V_H \geq 3,5V$.

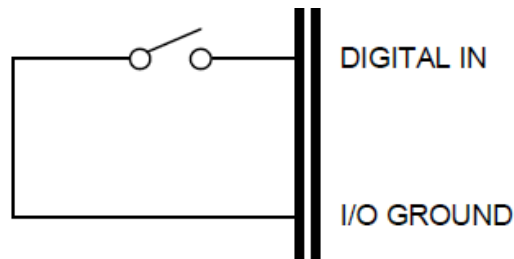


Figure 10 - Negative Logic for Digital Input

3.5.2 Analog Inputs

Analog Inputs on Controller			
Pin	Meaning	Pin	Meaning
K1 - 18	I/O Ground	K2 - 1	+5V Out
K1 - 21	+12V Out	K2 - 12	Analog Input 1
		K2 - 13	Analog Input 2
		K2 - 19	Analog Input 3
		K2 - 20	Analog Input 4
		K2 - 21	Analog Input 5
		K2 - 22	Analog Input 6

Wiring

All Analog Inputs are +5/12V pull down, the recommend resistance range of external potentiometer is 5÷10kΩ.

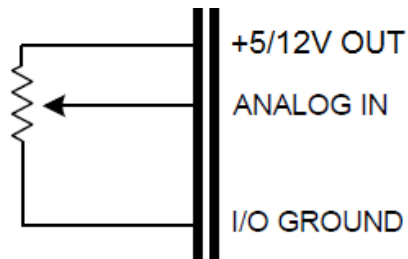


Figure 11 - Potentiometer connected to Analog Input

3.5.3 Driver Outputs (PWM)

Driver Outputs on Controller			
Pin	Meaning	Pin	Meaning
K1 - 9	Coil Return	K2 - 1	+5V OUT
K1 - 16	Driver Output 1 (Max 2A)		
K1 - 17	Driver Output 2 (Max 1.5A)		
K1 - 20	Driver Output 3 (Max 1.5A)		
K1 - 21	+12V Out		

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:

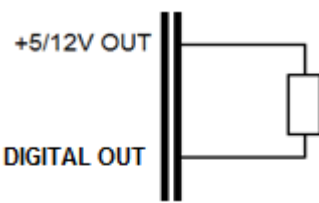
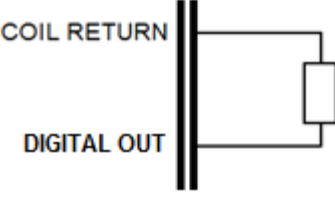
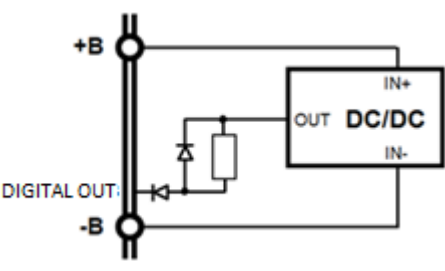
Driver Outputs Wiring on Controller		
Positive Reference	How to wire	
	Driver Output 1 – Driver Output 2	Driver Output 3
Controller +5/12V		
Battery Voltage		
External Supply from a DC/DC converter	Not Allowed	

3.5.4 Digital Outputs (ON/OFF)

Digital Outputs on Controller			
Pin	Meaning	Pin	Meaning
K1 - 8	Digital Output 1 (Max 1.5A)	K2 - 1	+5V OUT
K1 - 9	Coil Return		
K1 - 19	Digital Output 2 (Max 0.5A)		
K1 - 21	+12V OUT		

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	

3.5.5 Speed Sensor Inputs

Speed Sensor Inputs on Controller			
Pin	Meaning	Pin	Meaning
K1 - 21	+12V OUT	K2 - 1	+5V OUT
		K2 - 4	Quad Encoder Channel B
		K2 - 5	Quad Encoder Channel A
		K2 - 9	Negative Logic Supply

Wiring

The Encoder Channels are 20mA Pull-up with $V_L \leq 1V$ and $V_H \geq 3,5V$.

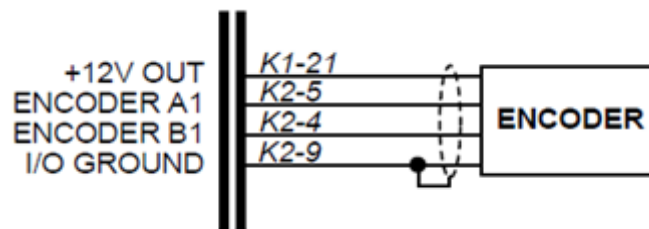


Figure 12 - Encoder Wiring

3.5.6 Thermal Probe

Speed Sensor Inputs on Controller			
Pin	Meaning	Pin	Meaning
K1 - 18	Negative Logic Supply	K2 - 10	Motor Temperature Probe

Wiring

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

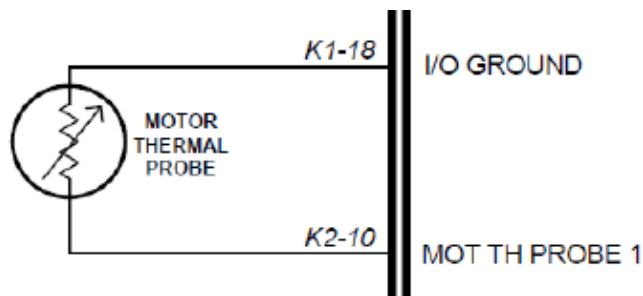


Figure 13 - Thermal Probe Wiring

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

3.5.7 Serial

Serial Pins on Controller	
Pin	Meaning
K1 – 11	RS-232 TX
K1 – 10	RS-232 RX
K1 – 18	Negative Logic Supply

Wiring

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

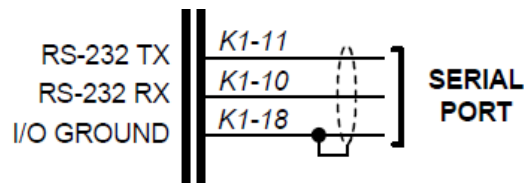


Figure 14 - Serial Wiring

The following picture represents the schematic of interconnection cable from the Controller to the Sub-D connector.

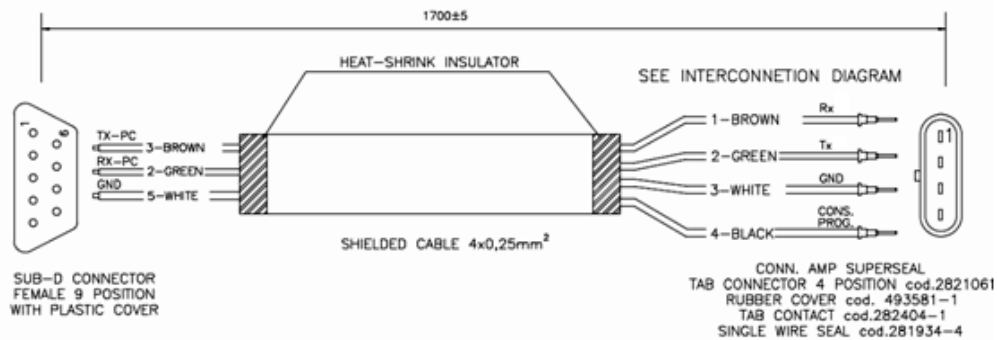


Figure 15

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

3.5.8 CAN Network

CAN Network Pins on Controller	
Pin	Meaning
K1 – 15	CAN - H
K1 – 23	CAN - L
K1 - 22	CAN Ground

Wiring

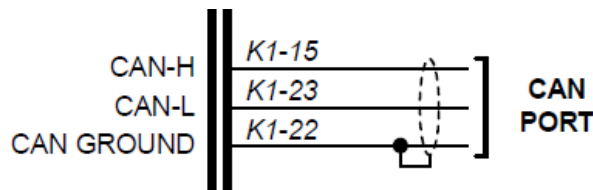
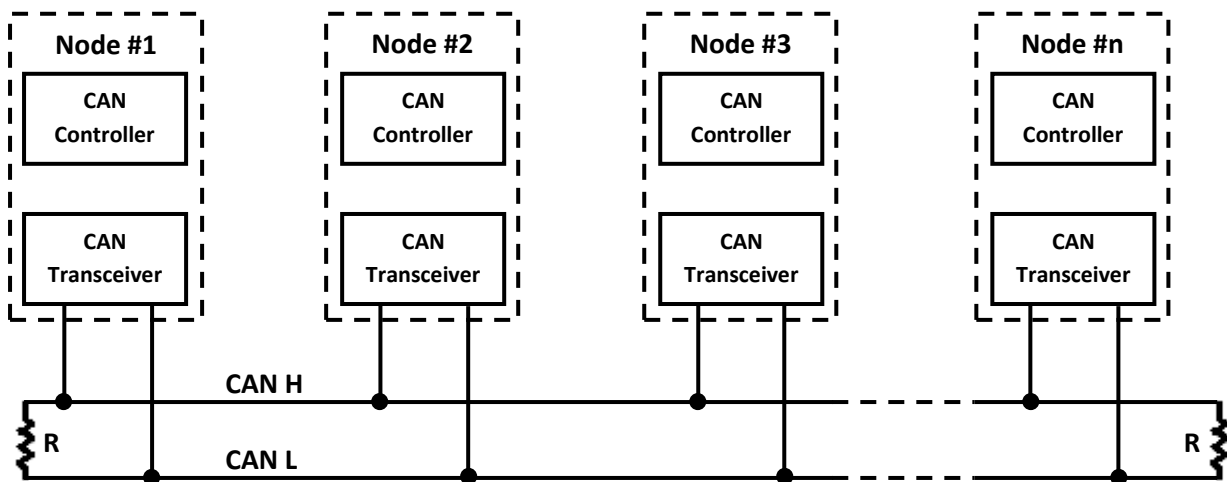


Figure 176 - CAN Network Wiring

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 unterminated 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.

3.6 SME external devices description

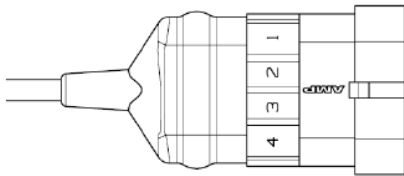
The Controller can be connected to SME external devices described below.

3.6.1 Encoder

The 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 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 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 18 - Display Compact



Figure 19 - 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.

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

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 Interactive Documentation.

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.

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:

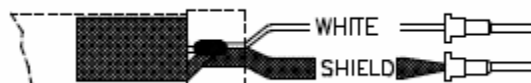
- The RF voltages and currents induced in each wire are applied to the controller pin to which the wire is connected. SME controllers include bypass capacitors on the printed circuit board's wires to reduce the impact of this source of noise on the internal circuitry, but in some applications an additional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

Appendix B: Document History

Rev. 1.1, June 2013:

Added a specification for driver output 3: if an inductive load is connected to the driver output 3 (K1-20), there is the necessity to add an external freewheeling diode anti-parallel connected as described in the wiring diagrams.

Corrected North-America region address.

Added supported USB-to-serial types.

Aligned Configure EM Brake parameters to actual SME GUI: now there is a tab for EM Brake and one for motor activation times.

Rev. 1.2, July 2013:

Corrected GUI images.

Rev. 1.3, December 2013:

Added dual traction system and CANopen net.

Rev. 2.0, December 2013:

Refactoring in all documentation and added references to single features user manual.

Rev. 2.1, January 2014:

Corrected front page and header. Deleted 3.10 paragraph. Some adjustment into 'General technical specification' paragraph.

Rev. 2.2, January 2014:

Added safety rules information.

Rev. 2.3, January 2014:

Corrected wiring diagrams (drive out 3 must be connected to +B).

Added connection description for drive outs below the first connector table.

Rev. 2.4, April 2014:

Corrected temperature range specifications.

Corrected SME Shangai company name.

Made more visible "the vehicle OEM takes full responsibility of the regulatory compliance of the vehicle system with the controller installed."

Restyled tables borders.

Rev. 2.5, May 2014:

Added deceleration lights in generic output.

Rev. 2.6, October 2014:

Changed SME Group logo.

Added crawl speed function in par. 4.16.

Rev. 3.0, March 2016:

Restyled contents.

Corrected SME references.