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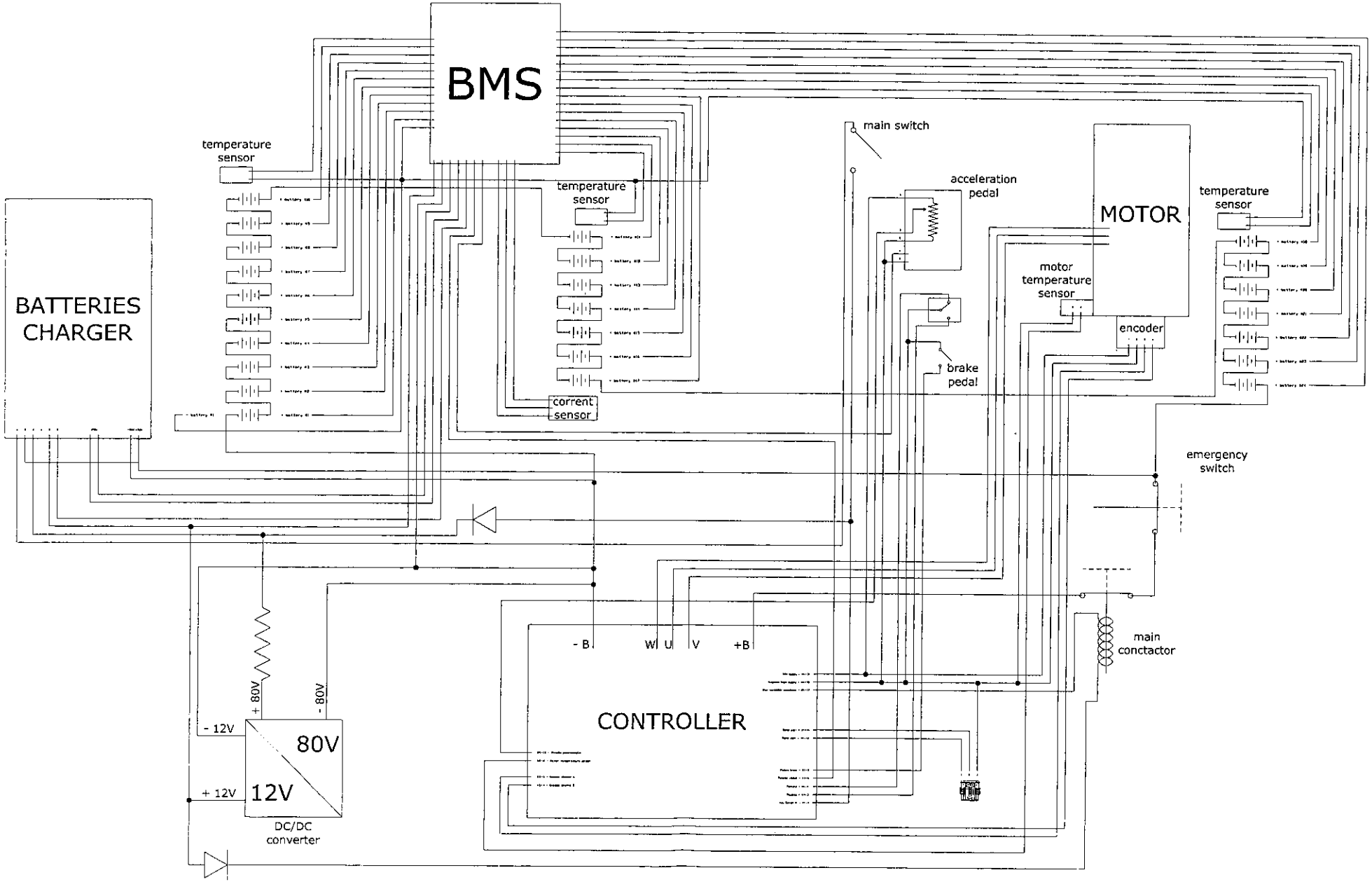
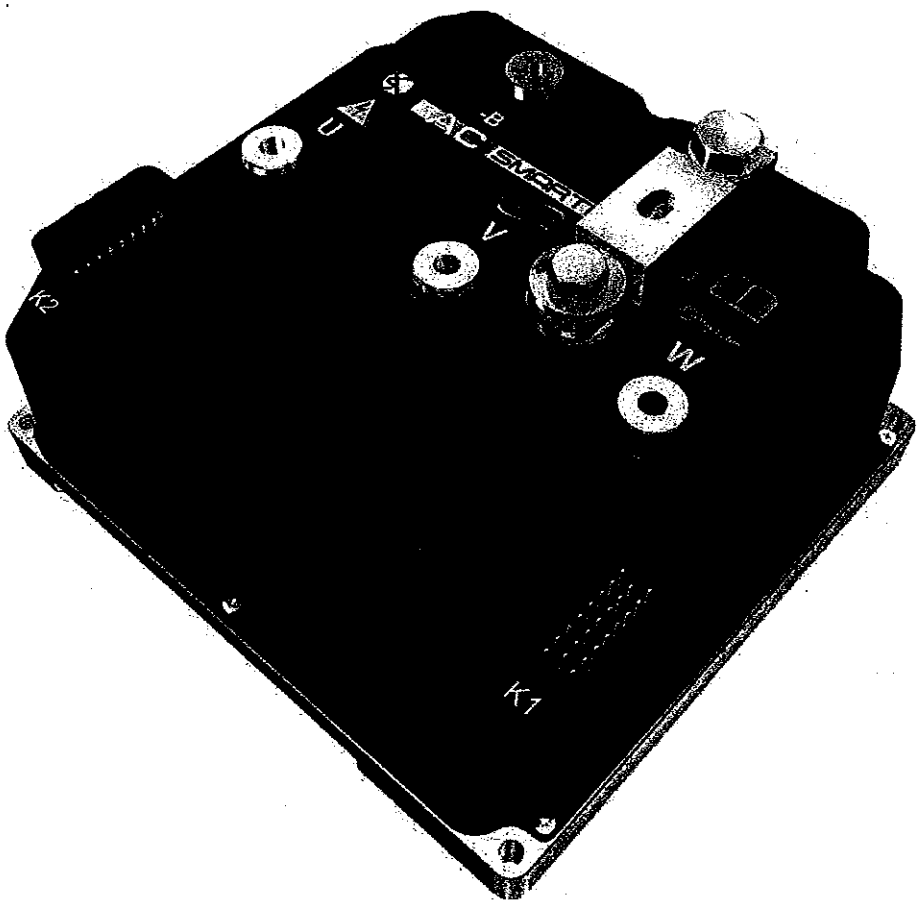


2. AC SmartMotion AC-L1 Overview



2.1 Product description

The AC-L1 Controller is designed to control AC motors.

Being based on high reliable DCB technology and exceptionally stable ITC Control Algorithm, AC-L1 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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2.2 General technical specifications

AC-L1 has the following remarkable features:

- ✓ Low $R_{DS,on}$ MOSFET
- ✓ 16 bits DSP controlling 1 AC motor
- ✓ High Speed FLASH Memory
- ✓ Integrated Hall Effect Current Sensors
- ✓ **Available Supply Voltages:** 36V, 48V, 72V, 80V
- ✓ **PWM Operating Frequency:** 9kHz
- ✓ **Communication:** Serial RS-232, LIN bus and CANOpen protocol
- ✓ **Maximum Current** (measured in a two-minute time interval):
  - ***36/48V version:*** $625A_{rms}$ / $750A_{rms}$
  - ***72/80V version:*** $600A_{rms}$ / $750A_{rms}$
- ✓ **Storage ambient temperature range:** -40°C ÷ +95°C
- ✓ **Operating ambient temperature range:** -40°C ÷ +55°C
- ✓ **Heatsink operating temperature range:** -40°C ÷ +95°C
  - ***With linear derating:*** +80°C ÷ +95°C
- ✓ **Mechanical Characteristics:**
  - ***Mechanical size:*** 210 x 190 x 91 [mm]
  - ***Weight:*** 3,8 kg
  - ***Connectors:*** 2x23 Ampseal terminals
  - ***Protection Level:*** IP65
  - Available with aluminium baseplate or finned heatsink
- ✓ **Vibration:** 5g, 10÷500Hz, 3 axes
- ✓ **I/O specifications:**
  - N° 19 + 2 Digital Inputs
  - N° 6 + 2 Analog Inputs
  - N° 2 Digital Outputs

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- N° 3 PWM Outputs

✓ **Regulatory compliance:**

- EN1175 for safety
- EN12895 for Electromagnetic compatibility
- UL Recognized Component; meets UL583 dielectric test

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

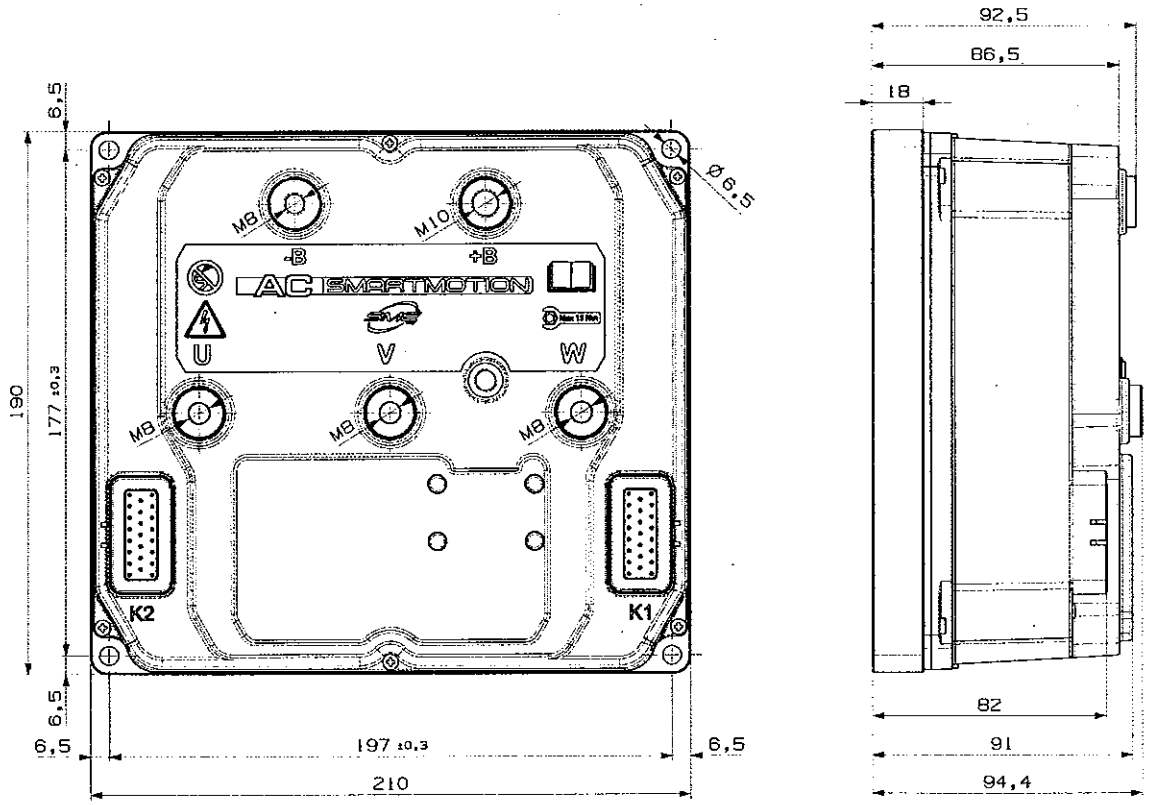

Figure 1: *AC-L1 technical drawings. All the dimensions are in millimeters.*

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The following model charts provide further details on the product family:

Model Chart for 24V version		
Model Name	AC Inverter Max Arms(2')	Max Power (2')
AC-L1 36/48V 625A	625 A_{rms}	34.6 kVA
AC-L1 36/48V 750A	750 A_{rms}	41.5 kVA

Model Chart for 36/48V version		
Model Name	AC Inverter Max Arms(2')	Max Power (2')
AC-L1 72/80V 600A	600 A_{rms}	55.4 kVA
AC-L1 72/80V 750A	750 A_{rms}	70 kVA

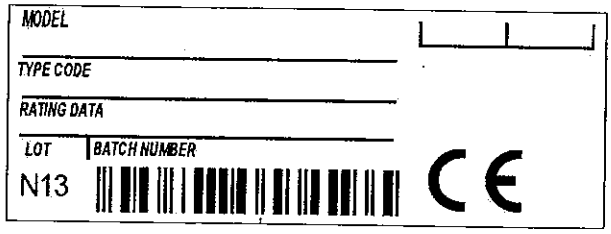
2.3 Packaging configuration

AC-M2 is available in one of the following packages:

1. with an aluminium baseplate;
2. with an aluminium baseplate and additional external heatsink.

2.4 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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3. Installation and wiring

3.1 General description

The AC-L1 is composed by a control section and a power section, both enclosed in a plastic cover with an aluminium baseplate or a heatsink on the bottom of the enclosure.

There is a power module which can be connected to a three-phase AC motor through the power outputs labelled as U, V, W.

Two 23 ways Ampseal connectors (named K1 and K2), permits to interface control board to vehicle system sub-devices (throttles, switches, potentiometers, etc..).

See following pages for the pin-out of these connectors.

There are two terminals (+B) and (-B) which supply the power module.

Please see Figure 1 for AC-L1 drawings.

SME recommends you to protect the AC-L1 against reversed battery polarity.

3.2 Mounting the controller

3.2.1 Overview

AC-L1 can be oriented in any direction and meets IP65 environmental protection rating. However, the location should be carefully chosen to keep the controller clean and dry.

If a clean, dry mounting location cannot be found, a cover should be used to shield the controller from water and contaminants.

The outline and mounting hole dimensions for the AC-L1 controller are shown in Figure 1.

To ensure full rated power, the controller should be fastened to a clean, flat metal surface with four 6.5 mm diameter bolts, using the holes provided.

A thermal joint compound must be used to improve heat conduction from the controller heatsink to the mounting surface.

During the design and development of your end product, you will need to ensure that its EMC performance complies with applicable regulations.

The AC-L1 controller contains **ESD-sensitive components.** Use appropriate precautions in connecting, disconnecting, and handling the controller.

For EMC and ESD purposes, SME strongly recommends that both the AC-L1 heatsink and the houses of the motors are connected to the chassis of the truck.

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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.
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.

3.2.2 Screw torque for the power connections

The recommended screw torque for fixing the connections (+B), (-B), U,V and W is 6 Nm.

This value is reported on the label placed on the cover: exceeding the recommended value may cause damages.

3.2.3 Connector parts

The K1 and K2 connectors are AMPSEAL 23 Pins, manufactured by AMP. The external plug assembly is AMP cod. 770680-1, with contact 0,5-1,4mm^2, cod. 770854-1.

3.3 Cooling requirements

3.3.1 AC-L1 with aluminium baseplate and additional heatsink

A massive heatsink comprising the entire bottom surface of the AC-L1 transfers heat out of the power conversion section to the surrounding air.

Drives operating at or near continuous power output require forced air cooling to maintain heatsink temperature in the safe operating zone.

We recommend ambient temperature air to be directed over the heatsink fins to maintain heatsink temperature below 85 °C.

Either an axial blower or two small fans can provide the necessary airflow.

3.3.2 AC-L1 with aluminium baseplate

A massive heatsink comprising the entire bottom surface of the AC-L1 transfers heat out of the power conversion section to the vehicle body.

Drives operating at or near their continuous power output require different thermal resistance depending on AC-L1 size for dissipation of heat to maintain heatsink temperature in the safe operating zone.

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In this case, AC-L1 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 AC-L1 is mounted.

Apply thermal grease to the AC-L1 before mounting for better cooling effect.

You should keep the planarity of the surface under 0.5mm, as shown in Figure 2.

3.3.3 Clearances

For all AC-L1 models 50 mm clearances in front of and behind the AC-L1 are required for airflow; 50 mm clearance above the AC-L1 is required for installation/removal of interface connectors and wiring. Refer to Figure 1 for the dimensions of AC-L1.

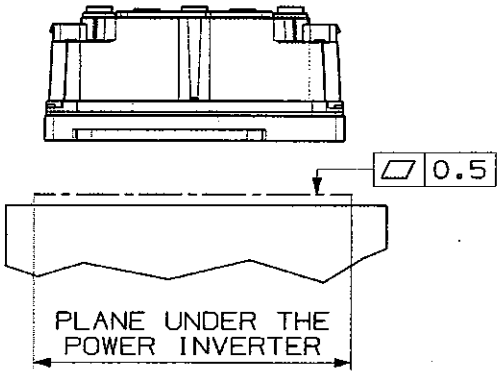

Figure 2: *Planarity specifications for the AC-L1 with aluminium baseplate.*

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3.4 List of complete pin-out

Refer to following tables for a complete AC-L1 controller K1 and K2 connectors pin-out.

K1 connector pin-out for AC-L1			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-L1
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 300mAmax	12V supply
22	CAN GROUND	-	-	CAN- bus negative supply
23	CAN-L	Com Input/Output	CAN-bus	CAN L (No internal termination resistor)

(*) 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.

Driver output 3 (K1-20) must be connected to the +B or to another supply source with the negative reference connected to the –B.

Driver out 1 (K1-16) and driver out 2 (K1-17) must be connected to the COIL RETURN.

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K2 connector pin-out for AC-L1				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**

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3.5 Typical connection diagram for basic TRACTION system

Figure below shows a connection diagram of a basic traction system using the AC-L1 as control board and an AC Induction Motor.

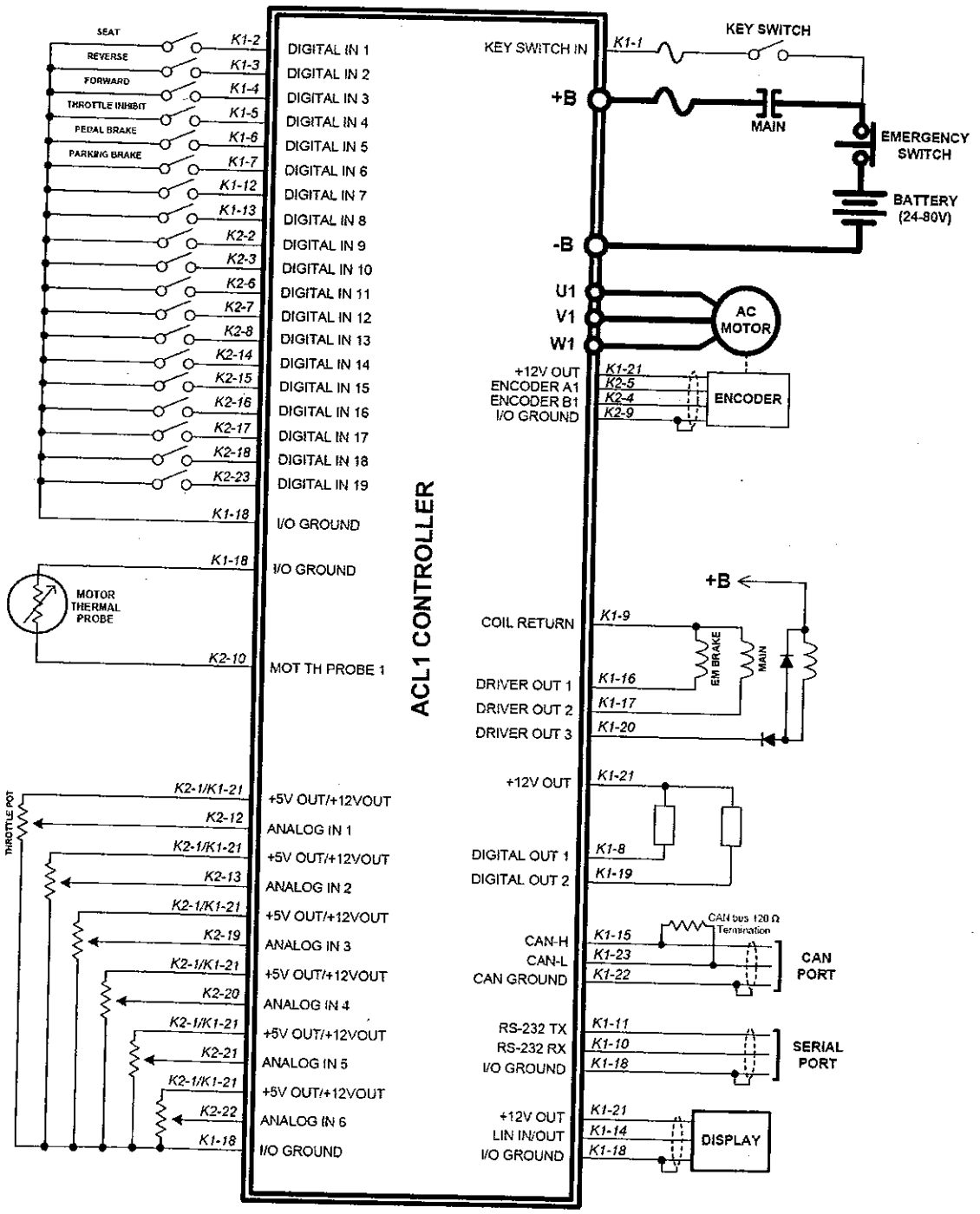

Figure 3: Traction basic wiring diagram.

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3.5.1 AC-L1 pin-out for basic TRACTION application

K1 connector pin-out for AC-L1 : basic TRACTION application		
Pin	**Name**	**Function**
1	KEY SWITCH IN	Positive supply of the control section of the AC-L1
2	DIGITAL IN 1	Seat switch
3	DIGITAL IN 2	Reverse direction
4	DIGITAL IN 3	Forward direction
5	DIGITAL IN 4	Throttle inhibit
6	DIGITAL IN 5	Pedal Brake
7	DIGITAL IN 6	Parking Brake
8	DIGITAL OUT 1	-
9	COIL RETURN	Positive common
10	RS-232 RX	Serial port
11	RS-232 TX	Serial port
12	DIGITAL IN 7	-
13	DIGITAL IN 8	-
14	LIN IN/OUT	LIN display connection
15	CAN-H	CAN H (No internal termination resistor)
16	DRIVER OUT 1	EM brake
17	DRIVER OUT 2	Main contactor command
18	I/O GROUND	Negative logic supply
19	DIGITAL OUT 2	-
20	DRIVER OUT 3 (*)	-
21	+12V OUT	12V supply
22	CAN GROUND	CAN- bus negative supply
23	CAN-L	CAN L (No internal termination resistor)

(*) 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.

Driver output 3 (K1-20) must be connected to the +B or to another supply source with the negative reference connected to the –B.

Driver out 1 (K1-16) and driver out 2 (K1-17) must be connected to the COIL RETURN.

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K2 connector pin-out for AC-L1 : basic TRACTION application		
Pin	**Name**	**Function**
1	+5V OUT	5V supply
2	DIGITAL IN 9	-
3	DIGITAL IN 10	-
4	ENCODER 1 B	Quad encoder channel B
5	ENCODER 1 A	Quad encoder channel A
6	DIGITAL IN 11	-
7	DIGITAL IN 12	-
8	DIGITAL IN 13	-
9	I/O GROUND	Negative logic supply
10	MOTOR THERMAL PROBE 1	Motor temperature probe
11	MOTOR THERMAL PROBE 2	-
12	ANALOG IN 1	Throttle potentiometer
13	ANALOG IN 2	-
14	DIGITAL IN 14	-
15	DIGITAL IN 15	-
16	DIGITAL IN 16	-
17	DIGITAL IN 17	-
18	DIGITAL IN 18	-
19	ANALOG IN 3	-
20	ANALOG IN 4	-
21	ANALOG IN 5	-
22	ANALOG IN 6	-
23	DIGITAL IN 19	-

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3.6 Typical connection diagram for basic PUMP system

Figure below shows a connection diagram of a basic pump system using the AC-L1 as control board and an AC Induction Motor.

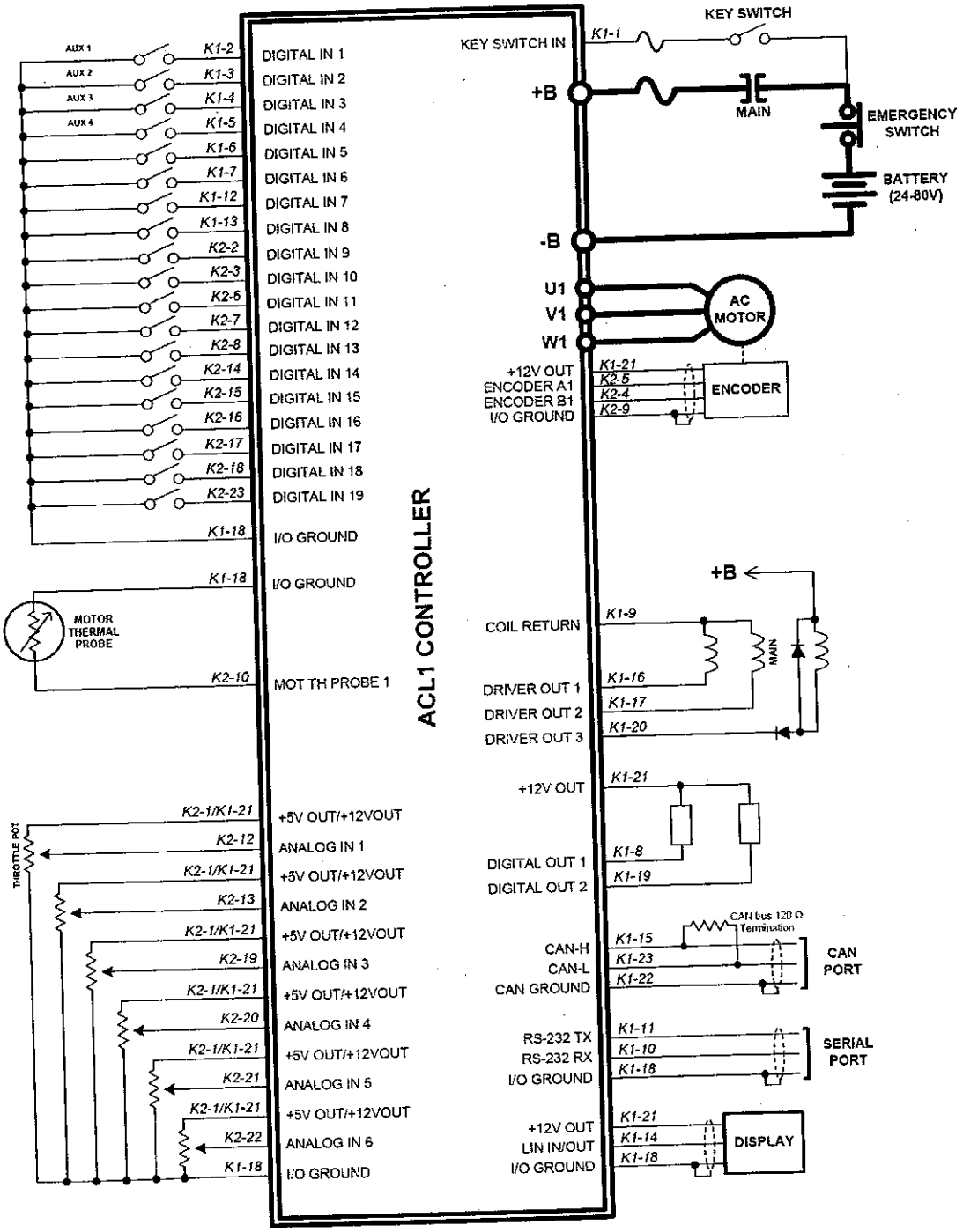

Figure 4: Pump basic wiring diagram.

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3.6.1 AC-L1 pin-out for basic PUMP application

K1 connector pin-out for AC-L1 : PUMP application		
Pin	**Name**	**Function**
1	KEY SWITCH IN	Positive supply of the control section of the AC-L1
2	DIGITAL IN 1	Auxiliary input 1
3	DIGITAL IN 2	Auxiliary input 2
4	DIGITAL IN 3	Auxiliary input 3
5	DIGITAL IN 4	Auxiliary input 4
6	DIGITAL IN 5	-
7	DIGITAL IN 6	-
8	DIGITAL OUT 1	-
9	COIL RETURN	Positive common
10	RS-232 RX	Serial port
11	RS-232 TX	Serial port
12	DIGITAL IN 7	-
13	DIGITAL IN 8	-
14	LIN IN/OUT	LIN display connection
15	CAN-H	CAN H (No internal termination resistor)
16	DRIVER OUT 1	-
17	DRIVER OUT 2	Main contactor command
18	I/O GROUND	Negative logic supply
19	DIGITAL OUT 2	-
20	DRIVER OUT 3 (*)	-
21	+12V OUT	12V supply
22	CAN GROUND	CAN- bus negative supply
23	CAN-L	L line input for CAN (No internal termination resistor)

(*) 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.

Driver output 3 (K1-20) must be connected to the +B or to another supply source with the negative reference connected to the –B.

Driver out 1 (K1-16) and driver out 2 (K1-17) must be connected to the COIL RETURN.

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K2 connector pin-out for AC-L1 : PUMP application		
Pin	**Name**	**Function**
1	+5V OUT	5V supply
2	DIGITAL IN 9	-
3	DIGITAL IN 10	-
4	ENCODER 1 B	Quad encoder channel B
5	ENCODER 1 A	Quad encoder channel A
6	DIGITAL IN 11	-
7	DIGITAL IN 12	-
8	DIGITAL IN 13	-
9	I/O GROUND	Negative logic supply
10	MOTOR THERMAL PROBE 1	Motor temperature input
11	MOTOR THERMAL PROBE 2	-
12	ANALOG IN 1	Throttle potentiometer
13	ANALOG IN 2	-
14	DIGITAL IN 14	-
15	DIGITAL IN 15	-
16	DIGITAL IN 16	-
17	DIGITAL IN 17	-
18	DIGITAL IN 18	-
19	ANALOG IN 3	-
20	ANALOG IN 4	-
21	ANALOG IN 5	-
22	ANALOG IN 6	-
23	DIGITAL IN 19	-

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