

**ELFA2  
Traction Inverter**

**Manual**

**ELFA2 DC4-650WM  
ELFA2 DC4-650WM-2  
ELFA2 DC4-650WM-C**

Edition: AH

Order Nr. A5E00468614F

The reproduction, transmission or use of this document or its contents is not permitted without express written authority. Offenders will be liable for damages. All rights, including rights created by patent grant or registration of a utility model or design, are reserved.

We have checked the contents of this Manual to ensure that they coincide with the described hardware and software. However, deviations cannot be completely ruled-out, so we cannot guarantee complete conformance. However, the information in this document is regularly checked and the necessary corrections included in subsequent editions. We are thankful for any recommendations or suggestions.

All product designations are trademarks or product names of Siemens AG

### Table of Contents:

<b>1</b>	<b>General data</b> .....	<b>4</b>
1.1	Legal information .....	4
1.2	ESD instructions .....	6
1.3	Warranty .....	6
1.4	List of abbreviations .....	6
1.5	Normative references .....	7
<b>2</b>	<b>Description of the product</b> .....	<b>8</b>
2.1	Type designation .....	8
2.2	Serial number .....	8
<b>3</b>	<b>Packing, transport and storage</b> .....	<b>9</b>
3.1	Packing .....	9
3.2	Transport .....	9
3.3	Storage .....	9
<b>4</b>	<b>Mounting</b> .....	<b>10</b>
4.1	Installing and mounting the traction inverter .....	10
4.2	Ground connections .....	11
4.3	Connecting-up the control cables .....	11
4.4	Connecting the power cables .....	12
4.5	Connecting-up the cooling water hoses .....	13
4.6	Removing the traction inverter, packing .....	14
4.7	Checking before commissioning .....	15
<b>5</b>	<b>Service/maintenance</b> .....	<b>16</b>
5.1	Service/maintenance intervals (maximum times) .....	16
5.2	Cleaning .....	16
5.3	Insulation resistance .....	16
<b>6</b>	<b>Information on troubleshooting/diagnostics</b> .....	<b>17</b>
6.1	Troubleshooting/diagnostics .....	17
<b>7</b>	<b>Electrical characteristics</b> .....	<b>18</b>
7.1	Overview traction inverter ELFA2 .....	18
7.2	Terminals .....	19
7.3	Power connections .....	19
7.4	Control connections .....	20
7.4.1	Signal interface to the vehicle X1 .....	20
7.4.2	Signal interface to motor/generator X2 .....	21
7.4.3	Signal interface to other traction inverters .....	21
7.5	Power rating traction inverter .....	22
7.5.1	Absolute maximum ratings .....	22
7.5.2	Dual inverter operation .....	23
7.6	DC-link .....	23
7.7	Power supply 12V / 24V .....	24
<b>8</b>	<b>Mechanical characteristics</b> .....	<b>25</b>
8.1	Dimensions / weight .....	25
8.2	Mechanical vibration test method (broad-band random) .....	25
8.3	Mechanical connections .....	25
<b>9</b>	<b>Environmental conditions</b> .....	<b>26</b>
9.1	Ambient Conditions .....	26
9.2	Chemical loads .....	26

---

<b>10</b>	<b>Cooling circuit .....</b>	<b>27</b>
<b>11</b>	<b>Electromagnetic compatibility (EMC).....</b>	<b>29</b>
<b>12</b>	<b>Protective measures .....</b>	<b>30</b>
12.1	Insulation .....	30
12.2	Protection concept.....	31
12.3	Fire protection measures .....	31
<b>13</b>	<b>Service life/Reliability .....</b>	<b>32</b>
13.1	Life utility/Service life.....	32
13.2	Mean time between failures (MTBF).....	32
13.3	Quality assurance.....	32
13.4	Adjustment, repair, maintenance and diagnosis .....	32
<b>14</b>	<b>Attachment to user information.....</b>	<b>33</b>
14.1	Tool and material list .....	33
14.2	Attachments .....	33
14.3	Change Index .....	33

# 1 General data

## 1.1 Legal information

- Warning notice system**

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

**DANGER**

indicates that death, severe personal injury and/or substantial property damage **will** result if proper precautions are not taken.

**WARNING**

indicates that death, severe personal injury and/or substantial property damage **may** result if proper precautions are not taken.

**CAUTION**

with a safety alert symbol, indicates that minor personal injury and/or property damage can result if proper precautions are not taken.

**CAUTION**

without a safety alert symbol, indicates that property damage can result if proper precautions are not taken.

**NOTICE**

indicates that an unintended result or situation can occur if the corresponding information is not taken into account.

Or:

indicates information about the product or the respective part of the Manual which is essential to highlight.

- QUALIFIED PERSONNEL**

**WARNING**

The device/system may only be set up and used in conjunction with this manual. Commissioning and operation of a device/system may only be performed by qualified personnel. Within the context of the safety notes in this documentation qualified persons are defined as persons who are authorized to commission, ground and label devices, systems and circuits in accordance with established safety practices and standards. He or she must have the following qualifications:

1. Trained and authorized to energize, de-energize, clear, ground and tag circuits and equipment in accordance with established safety procedures.
2. Trained in the proper care and use of protective equipment in accordance with established safety procedures.
3. Trained in rendering first aid.

- **Proper use of Siemens products**

**⚠ WARNING**

- Siemens products may only be used for the applications described in the relevant technical documentation. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be adhered to. The information in the relevant documentation must be observed.
- Electrical equipment has components which are at dangerous voltage levels.
- The personnel must take into account the information provided in the technical documentation for the product, and be familiar with and follow the specified danger and warning notices.
- In addition to the danger and warning information provided in the technical customer documentation, the applicable national, local, and system-specific regulations and requirements must be taken into account.
- Operation of the traction inverter at a stationary grid is not allowed.

**⚠ CAUTION**

- This equipment may only be used for the purpose specified by the manufacturer. Unauthorized modifications and the use of spare parts and accessories that are not sold or recommended by the manufacturer of the equipment can cause fires, electric shocks and injuries.

**NOTICE**

- The information in this Manual does not purport to cover all details or variations in equipment, or to provide Information for every possible contingency to be met in connection with installation, operation or maintenance.
- Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, please contact your local Siemens office.
- Further, the contents of this Manual shall neither become a part of nor modify any prior or existing agreement, commitment or relationship. The sales contract contains the entire obligation of Siemens. The warranty contained in the contract between the parties is the sole warranty of Siemens. Any statements contained herein neither create new warranties nor modify the existing warranty.
- This Manual deals exclusively with the traction inverter (refer to section 2.1).
- Thus, additional information about the operating conditions and vehicle design is not part of this Manual.
- The traction inverter is only operational in a complete system including external components such as generator, traction motor etc.
- Keep this manual within easy reach of the equipment and make it available to all users.

- **Information on copyrights and trademark rights**

The instructions and information in the documentation are copyrighted by the manufacturer and may therefore not be passed on to third parties.

Although circuits or techniques could be described in this Manual, this does not mean that they are not copyrighted. Patents or copyrights of Siemens AG or third parties could exist.

### 1.2 ESD instructions

#### Unit contains components which can be destroyed by electrostatic discharge (ESD)

Do not open the unit (except terminal covers). Return defective equipment to the manufacturer, who will make the necessary repairs.



### 1.3 Warranty

#### NOTICE

If the traction inverter is returned to Siemens AG under warranty, then the following documents are necessary so that claims can be made under warranty.

- Use the advice of the return form of the Siemens Customer Service
- Fill out and send: "Return information ELFA" (refer to section 14.2)
  - Serial number of the traction inverter
  - Fault description (do not erase the fault memory!)
  - Total number of kilometers that the vehicle has been operated
  - Fault memory

Siemens AG reserves the right to request additional information.

The traction inverter must be carefully and professionally packed for transport. Damages incurred during transport are not covered by warranty.

Siemens cannot accept any claims under warranty if the equipment was incorrectly operated, mounted, installed and commissioned.

### 1.4 List of abbreviations

Abbreviation	Designation
AC	Alternating current
AINP	Analog Input 0 - 5 V
DC	Direct current
DICO	Digital output control
DIL	Digital input low-active 24 V internal
DIH	Digital input high-active GND internal
DOL	Digital output low-active switches according to ground
ESD	Electrostatic discharge
HV	High voltage
MCB	Motor Control Board
OEM	Original equipment manufacturer
PE	Protective earth connection

## 1.5 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the cited edition applies. For undated references, the edition valid on date of test of the referenced document (including any amendments) applies.

ISO 16750-1 / 2006, Road vehicles - Environmental conditions and testing for electrical and electronic equipment - Part 1: General
ISO 16750-2 / 2006, Road vehicles - Environmental conditions and testing for electrical and electronic equipment - Part 2: Electrical loads
ISO 16750-3 / 2007, Road vehicles - Environmental conditions and testing for electrical and electronic equipment - Part 3: Mechanical loads
ISO 20653 / 2006, Road vehicles - Degrees of protection (IP-Code) - Protection of electrical equipment against foreign objects, water and access
IEC 60721-3-5 / 1997, Classification of environmental conditions - Part 3: Classification of groups of environmental parameters and their severities - Section 5: Ground vehicle installations
EN 50124-1 / 2001 + A1 / 2003 + A2 / 2005, Railway applications - Insulation coordination - Part 1: Basic requirements; Clearances and creepage distances for all electrical and electronic equipment
SN 29500-1 / 2004, Failure rates of components; expected values, General

## 2 Description of the product

### 2.1 Type designation

- Manufacturer and supplier

Manufacturer	Supplier
Siemens AG, Industry Sector DT LD TD	

- Product numbers

Product numbers	Product Name	Note
A5E02503560	ELFA2 DC4-650WM	
A5E02049710	ELFA2 DC4-650WM-2	
A5E00468614	ELFA2 DC4-650WM-C	

### 2.2 Serial number

The serial number includes the date of manufacture, product group or profit center and a consecutive number.

**N – V 1 31 5217 - 00010**  
 | | | | | |  
 | | | | | |  
**1 2 3 4 5 6**

- 1 Location of manufacturing (N = Nuremberg)
- 2 Year of manufacture (V = 2007, W = 2008, X = 2009, A = 2010, ...)
- 3 Month of manufacture (1 = January, 2 = February, ..., O = October, N = November, ...)
- 4 Day of manufacture
- 5 Profit center
- 6 Consecutive number

According to the example above, the date of manufacture was 31.01.2007.



## 3 Packing, transport and storage

### 3.1 Packing

- The traction inverter must be mounted and transported on a sufficiently large supporting surface.
- The control-, power- and water connections and the front terminal box opening of the traction inverter must be protected against the ingress of water and dirt (e.g. using caps or another appropriate method of covering them). The upper terminal box opening has to be closed using the respective cover.
- Remove protecting caps or tape only right before connecting cables and hoses.

### 3.2 Transport

<b>NOTICE</b>
<ul style="list-style-type: none"> <li>• Protect the equipment against physical shocks and vibration during transport and storage. It is important that the equipment is protected from water (rainfall) and excessive temperatures.</li> <li>• If the traction inverter is subject to significant jolts (for example, because it has been dropped), then do not use it in case it has been internally damaged and return it to the manufacturer.</li> <li>• The coolant connections which stick out of the module must never be used as handles or support surfaces when the units are transported.</li> </ul>

### 3.3 Storage

<b>CAUTION</b>
<ul style="list-style-type: none"> <li>• It is not permissible to               <ul style="list-style-type: none"> <li>- stack the traction inverters</li> <li>- load it with the weight of other objects.</li> </ul> </li> <li>• Protect against water. Only store the traction inverter with the control-, power- and water connections and the two terminal box covers closed-off. Power cable glands should be sealed using adhesive tape or filler plugs.</li> <li>• When storing the traction inverter, ensure that the permissible storage temperatures are observed. Refer to section 9.1.</li> <li>• Aluminum electrolytic capacitors can be stored for a minimum of two years under no-voltage conditions without reducing their reliability. Within this time period, they can be used at their rated voltage without any special measures having to be made. However, if they are stored for longer than two years in a no-voltage condition (especially at high temperatures), then they must be reformed (refer to section 4.7 "Checking before commissioning"). The storage time can be determined from the date the device was manufactured from the serial number on the rating plate (refer to section 2.2 "Serial number").</li> </ul>

## 4 Mounting

### 4.1 Installing and mounting the traction inverter

The following procedure must be observed:

- Unpack the traction inverter. Packing materials must be disposed of in-line with local regulations.
- Visibly check the equipment for damage during transport and if required, clean the outside of the unit (e.g. using moist cloth). Refer to section 5.2 "Cleaning"
- Transporting: Refer to section 3.2 "Transport".
- Installing the traction inverter:  
Mechanically retain the traction inverter (e.g. 4 M 8 bolts). Use spring washers and washers. Refer to the respective "dimension drawing" (refer to section 14.2).

#### WARNING

If the order for installing and mounting of the traction inverter (refer to sections 4.1 to 4.5) is not followed, this can result in death, serious injury and significant material damage.

#### CAUTION

- The preferable mounting position is horizontal.
- The vertical mounting position with X1/X2 on bottom is not allowed.
- When mounting on rigid surfaces, gaps >1mm can occur due to tolerances of the traction inverter and the mounting frame which must be filled-out at the mounting points using compensation elements.
- The traction components may not be handled or lifted by their cables. During assembly and operation tensile forces up to 20 N are permissible.

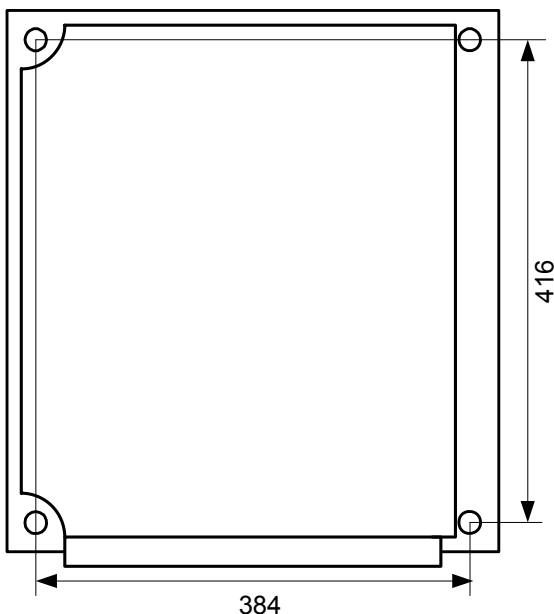



Fig. 4.1 Position of the mounting bolts

## 4.2 Ground connections

Refer to the respective “dimension drawing” (refer to section 14.2) or to Fig. 4.2 for the position of the ground / protective earth connection.

	<b>⚠ WARNING</b>
	<ul style="list-style-type: none"> <li>• The inverter must always be connected to the vehicle chassis using the ground / protective earth connection.</li> <li>• Observe the sequence of the connection: Cooling plate - cable lug - washer - spring washer - screw M 8, tightening torque 15 Nm.</li> </ul>

## 4.3 Connecting-up the control cables



Refer to the respective “dimension drawing” (refer to section 14.2) for the position of the control connectors.

- The control connection between the vehicle and the traction inverter is established by inserting and fixing the 32-pin plug connector X1.
- The connection between pulse encoder signals from the motor and the traction inverter is established by inserting and fixing the 9-pin plug connector X2.
- The control connection between two inverters is established by inserting and fixing the 32-pin plug connector X9 (only used when two inverters are in parallel mode).

<b>CAUTION</b>
<ul style="list-style-type: none"> <li>• The control cable connections must be strain-relieved.</li> <li>• Only insert the control connectors when the equipment is in a no-voltage condition.</li> <li>• The shielding of the pulse encoder cable (connected to X2) must be connected to the respective cable gland.</li> <li>• If the wrong cable gland insert is chosen, the protection degree against dirt and water is not guaranteed.</li> <li>• Unused control connections have to be closed using appropriate caps or installing the respective control connector with a filler plug.</li> </ul>

<b>NOTICE</b>
<ul style="list-style-type: none"> <li>• The tightening torque for signal connectors M 5 is 2,5 Nm.</li> <li>• The tightening torque for control cable glands M 20 is 10 Nm.</li> <li>• The tightening torque for control cable glands M 16 is 8 Nm.</li> <li>• Refer to the respective “dimension drawing” (refer to section 14.2).</li> </ul>

#### 4.4 Connecting the power cables

	 <b>WARNING</b>
	<p>Before starting work, the following “<b>five safety rules</b>” for the entire high-voltage system must be observed:</p> <ol style="list-style-type: none"> <li><b>1. Disconnect the system (De-energize the supply).</b></li> <li><b>2. Protect against reconnection.</b></li> <li><b>3. Make sure that the equipment is de-energized.</b></li> <li><b>4. Ground and short-circuit.</b></li> <li><b>5. Cover or enclose adjacent components that are still live.</b></li> </ol> <p><b>Note:</b></p> <ul style="list-style-type: none"> <li>• Even after the traction inverter has been powered-down, hazardous voltages can still be present for longer periods of time.</li> <li>• It takes <b>about 3 min</b> for the DC link capacitors to discharge down to non-hazardous voltage levels.</li> </ul> <p><b>If this information/instructions are not followed, this can result in death, serious injury and significant material damage.</b></p>

<b>CAUTION</b>
<ul style="list-style-type: none"> <li>• If one of the terminal box covers or one of the control connections is opened the degree of protection of the traction inverter is IP00. Beware of bringing dust, water or other parts into the housing of the inverter.</li> <li>• The power cable connections must be strain-relieved.</li> <li>• When connecting the power cables, observe the markings on the cables and the respective drawings of the wiring harness.</li> <li>• The shielding of the power cables must be connected to the respective cable glands.</li> <li>• The power cables may only be connected using crimpable tubular cable lugs.</li> <li>• The contact surface of the cable lugs and the terminal bar has to be clean.</li> <li>• Any use of screw locking varnish is forbidden.</li> <li>• All screws M 10 of the terminal box have to be tightened.</li> <li>• Close the two terminal box covers, use all of the screws in order to achieve the required level of sealing.</li> <li>• All of the power cable glands must be closed.</li> <li>• If the wrong cable gland insert is chosen, the protection degree against dirt and water is not guaranteed.</li> </ul>

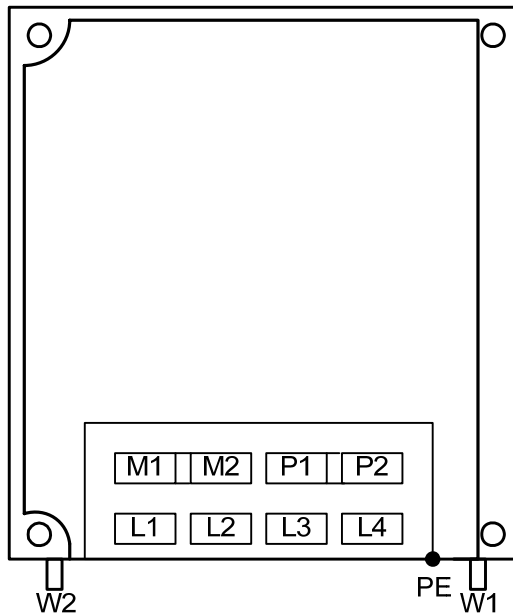


Fig. 4.2 Connecting the traction inverter power cable

List of incoming cables from left to right, lower connections:

Connection	Cable cross-section	Connection	Designation
L1	35 mm <sup>2</sup> or 50 mm <sup>2</sup> or 70 mm <sup>2</sup>	M 10	Phase 1
L2	35 mm <sup>2</sup> or 50 mm <sup>2</sup> or 70 mm <sup>2</sup>	M 10	Phase 2
L3	35 mm <sup>2</sup> or 50 mm <sup>2</sup> or 70 mm <sup>2</sup>	M 10	Phase 3
L4	35 mm <sup>2</sup> or 50 mm <sup>2</sup> or 70 mm <sup>2</sup>	M 10	Phase 4
PE	min 35 mm <sup>2</sup>	M 8	Ground / protective earth connection

List of incoming cables from left to right, upper connections:

Connection	Cable cross-section	Connection	Designation
M1	35 mm <sup>2</sup> or 50 mm <sup>2</sup> or 70 mm <sup>2</sup>	M 10	DC negative
M2	35 mm <sup>2</sup> or 50 mm <sup>2</sup> or 70 mm <sup>2</sup>	M 10	DC negative
P1	35 mm <sup>2</sup> or 50 mm <sup>2</sup> or 70 mm <sup>2</sup>	M 10	DC positive
P2	35 mm <sup>2</sup> or 50 mm <sup>2</sup> or 70 mm <sup>2</sup>	M 10	DC positive

### NOTICE


- The tightening torque for power connections M 10 is 30 Nm
- The tightening torque for power cable glands M 25 is 22 Nm.
- The tightening torque for the two terminal box covers M 5 is 3,7 Nm.
- Refer to the respective “dimension drawing” (refer to section 14.2).

Unused power cable connections have to be closed using filler plugs.

## 4.5 Connecting-up the cooling water hoses

Remove the protective caps from W1 and W2, connect the cooling water hoses without strain at the connection and secure with clamps. W1 is the cooling water inlet and W2 is the cooling water discharge (see figure 4.2 or refer to the respective “dimension drawing” (refer to section 14.2)). The system must be filled and then vented to remove air.

#### 4.6 Removing the traction inverter, packing

	<b>⚠ WARNING</b>
	<p>Before starting work, the following “<b>five safety rules</b>” for the entire high-voltage system must be observed:</p> <ol style="list-style-type: none"> <li><b>1. Disconnect the system (De-energize the supply).</b></li> <li><b>2. Protect against reconnection.</b></li> <li><b>3. Make sure that the equipment is de-energized.</b></li> <li><b>4. Ground and short-circuit.</b></li> <li><b>5. Cover or enclose adjacent components that are still live.</b></li> </ol> <p><b>Note:</b></p> <ul style="list-style-type: none"> <li>• Even after the traction inverter has been powered-down, hazardous voltages can still be present for longer periods of time.</li> <li>• It takes <b>about 3 min</b> for the DC link capacitors to discharge down to non-hazardous voltage levels.</li> </ul> <p><b>If this information/instructions are not followed, this can result in death, serious injury and significant material damage.</b></p>

<b>⚠ WARNING</b>
<ul style="list-style-type: none"> <li>• If the order for removing the traction inverter (given below) is not followed, this can result in death, serious injury and significant material damage.</li> <li>• When releasing the cooling medium pipes, hot cooling medium may cause serious injury.</li> </ul>

<b>CAUTION</b>
The cooling medium has to be removed completely, in order to protect the cooling plate.

- Release the pressure in the cooling system
- Drain the cooling medium, remove the cooling medium pipes.  
The cooling medium should be flushed out with water. If not possible the cooling medium should be blown out with clean air.
- Close the water connections W1 and W2
- Release the power cables.
- Close the upper terminal box cover.
- Release the control connectors X1, X2 and X9.
- Close control connectors X1, X2 and X9 using appropriate caps.
- Release the protective conductor.
- Release the mechanical connections between the inverter and mounting.
- Raise the inverter from the mounting (refer to Section 3.2 "Transport").
- Pack, transport and load, refer to Sections 3.1 to 3.3.

## 4.7 Checking before commissioning

Only qualified personnel may commission the equipment, observing Section 1 "General data" especially the warning information.

A special step-by-step commissioning is not required. The traction inverter has been designed so that it will function properly after it has been correctly connected-up and the power supply has been powered-up. The control board (MCB) contains no software when the equipment is shipped (unless otherwise expressly agreed). The download of the software and parameterization (e.g. speed, torque, max. output) is realized when the vehicle control is commissioned by the OEM.

### CAUTION

Before the equipment is commissioned, the following checks must be made:

- Visible check for damage.
- Check the storage time (if the equipment has been stored for two years or more, it will be necessary to reform the electrolytic capacitors in the unit).
- Check that the equipment has been correctly installed and mounted.
- Check that all of the mounting screws between the traction inverter and housing are tight.
- Connections and tightness of connections:
  - all of the power connections and the protective earth connections.
  - all of the control circuit connectors.
  - the water connections.

### CAUTION

Aluminum electrolytic capacitors can be stored for a minimum of two years under no-voltage conditions without reducing their reliability. Within this time period, they can be used at their rated voltage without any special measures having to be made.

However, if they are stored for longer than two years in a no-voltage condition (especially at high temperatures), then they must be reformed. The storage time can be determined from the date the device was manufactured from the Serial number on the rating plate. Refer to section 2.2.

Reforming:

a) DC voltage

600V DC is connected through a series resistor of approx. 200 ohms at terminals P and M.

Duration 2 hours.

or

b) AC voltage

single-phase 380V AC (<450V) is connected at terminals L1 and L2 through a series resistor of approx. 200 ohm. In this case, the free-wheeling diodes in the inverter act as rectifier.

Duration 2 hours.

The series resistor has to be chosen according the voltage and power requirements.

## 5 Service/maintenance

### 5.1 Service/maintenance intervals (maximum times)

The traction inverter is maintenance-free. Only the cooling system of the vehicle has to be occasionally checked.

Activity	Interval
Checking the cooling medium	2 years



The specified service interval is a maximum value. The actual maintenance intervals depend on the type and amount of dirt accumulation and must be defined according to the operating experience.

The cooling system and the cooling medium has to satisfy the specifications given in the respective Section 10 "Cooling circuit".

### 5.2 Cleaning

<b>CAUTION</b>
<ul style="list-style-type: none"> <li>• Only clean the exterior of the unit.</li> <li>• Solvents and compressed air are forbidden.</li> <li>• High-pressure cleaners using either steam or water should be avoided.</li> </ul>

### 5.3 Insulation resistance

 <b>WARNING</b>
<div style="display: flex; align-items: center;"> <div style="flex: 1;">  </div> <div style="flex: 2;"> <p>Before starting work, the following <b>"five safety rules"</b> for the entire high-voltage system must be observed:</p> <ol style="list-style-type: none"> <li><b>1. Disconnect the system (De-energize the supply).</b></li> <li><b>2. Protect against reconnection.</b></li> <li><b>3. Make sure that the equipment is de-energized.</b></li> <li><b>4. Ground and short-circuit.</b></li> <li><b>5. Cover or enclose adjacent components that are still live.</b></li> </ol> <p><b>Note:</b></p> <ul style="list-style-type: none"> <li>• Even after the traction inverter has been powered-down, hazardous voltages can still be present for longer periods of time.</li> <li>• It takes <b>about 3 min</b> for the DC link capacitors to discharge down to non-hazardous voltage levels.</li> </ul> <p><b>If this information/instructions are not followed, this can result in death, serious injury and significant material damage.</b></p> </div> </div>

For the measurement of the insulation resistance refer to the document "Measurement insulation resistance ELFA2" (refer to section 14.2). For the value of the insulation resistance refer to Section "Insulation" (refer to section 12.1).



## 6 Information on troubleshooting/diagnostics

### 6.1 Troubleshooting/diagnostics

NOTICE
<p>Do not erase the error buffer. Information can be obtained about the fault(s) which occurred by evaluating the error report. The error message is important for documenting the operating behavior.</p>

## 7 Electrical characteristics

### NOTICE

The following data are generally valid for the traction inverter. In the actual application, other data could apply. Please refer to the vehicle description.

### 7.1 Overview traction inverter ELFA2

#### Design characteristics

- Water-cooled, compact low-weight design.
- The power supply supports 12V and 24V applications.
- The traction inverter shall be operated at typical 650V DC systems.

#### Supply

- The supply can be for example one of the following: Battery / UltraCap / Fuel cell / an additional inverter with generator / Combination of battery and inverter with generator = hybrid.

#### Voltage DC link

- The voltage DC link comprises DC link capacitors and the continuous discharge resistor.
- The tasks of the DC link are as follows: Stabilizing the DC link voltage / Absorbtion of AC current components / Supplying reactive power for the load / Buffering the regenerative energy when a load is rejected.
- Discharging the DC link capacitors when powered-down through the continuous discharge resistor to a value of 60V in less than 3 min.

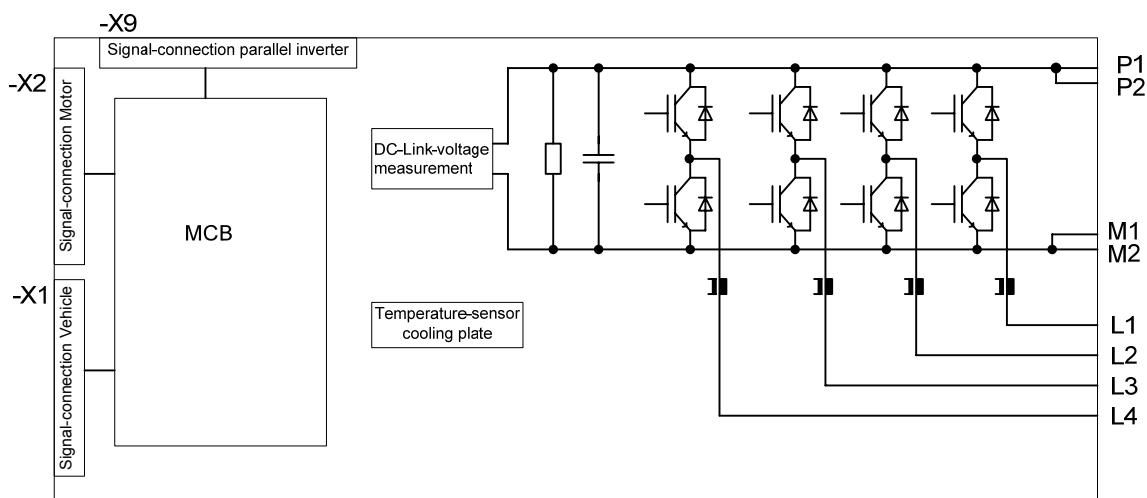
#### Traction inverter

- The Traction inverter comprises 4 identical phases with IGBT modules.

#### Closed-loop control, MCB

- The control board MCB realizes the following functions. It generates the pulse pattern for the PWM inverter, converts setpoints for torque and speed and provides control-dependent protective functions such as voltage-, current-, speed-, temperature monitoring.
- A CAN bus is used to communicate with other system components via connector X1.

#### Block diagramm






## 7.2 Terminals

- The drive components may not be handled or lifted by their cables. During assembly and operation tensile forces up to 20 N are permissible.
- Use the correct insert for the EMC cable glands depending on the cable cross-section of the used power cable.

## 7.3 Power connections

- The power cables should only be connected using crimpable tubular cable lugs.
- The power cable connections must be strain-relieved.
- Maximum length of cable between 2 traction inverters: 3m.  
The use of longer cables has to be discussed with Siemens AG.

 <b>DANGER</b>	
<ul style="list-style-type: none"> <li>• When connecting any kind of energy source to the power connections of the traction inverter, e.g. a traction battery, UltraCap, SuperCap, generator, permanent-field motor,...., the user has to make sure that the energy flow is stopped immediately if there is a failure in the drive system.</li> <li>• In any case of failure with failure currents above 300 Arms the maximum permissible I<sup>2</sup>t-value is 45.000 A<sup>2</sup>s.</li> <li>• In any case of failure with failure currents below 300 Arms the current flow has to be stopped in less than one second.</li> </ul>	

	 <b>WARNING</b>
	<ul style="list-style-type: none"> <li>• The inverter must always be connected to the vehicle chassis using the ground / protective earth connection.</li> </ul>

<b>CAUTION</b>	
<ul style="list-style-type: none"> <li>• The cross-section of the power cables has to be chosen in such a way that the temperature of the cable doesn't exceed 105°C.</li> <li>• If others components (e.g. auxiliary drives) are connected to the same DC-Link as the traction inverter, the user has to make sure that the currents in the DC-Link doesn't overload any component.</li> </ul>	

Connection	Cable cross-section	Connection	Designation
L1	35 mm <sup>2</sup> or 50 mm <sup>2</sup> or 70 mm <sup>2</sup>	M 10	Phase 1
L2	35 mm <sup>2</sup> or 50 mm <sup>2</sup> or 70 mm <sup>2</sup>	M 10	Phase 2
L3	35 mm <sup>2</sup> or 50 mm <sup>2</sup> or 70 mm <sup>2</sup>	M 10	Phase 3
L4	35 mm <sup>2</sup> or 50 mm <sup>2</sup> or 70 mm <sup>2</sup>	M 10	Phase 4
M1	35 mm <sup>2</sup> or 50 mm <sup>2</sup> or 70 mm <sup>2</sup>	M 10	DC negative
M2	35 mm <sup>2</sup> or 50 mm <sup>2</sup> or 70 mm <sup>2</sup>	M 10	DC negative
P1	35 mm <sup>2</sup> or 50 mm <sup>2</sup> or 70 mm <sup>2</sup>	M 10	DC positive
P2	35 mm <sup>2</sup> or 50 mm <sup>2</sup> or 70 mm <sup>2</sup>	M 10	DC positive
PE	min 35 mm <sup>2</sup>	M 8	Protective earth connection

### 7.4 Control connections

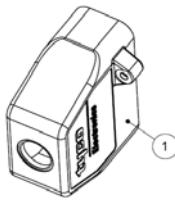
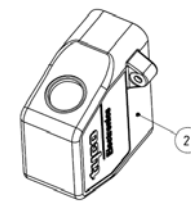
- The control cable connections must be strain-relieved.
- All cables for connecting the drive components via connector X1, X2 or X9 have to have a cross-section of 0.5 mm<sup>2</sup> to 1 mm<sup>2</sup>.
- Power supply cables for connector X1 (Pin No. 1-4) have to have a cross-section of 1.5 mm<sup>2</sup>.

#### WARNING

KL31 of connector X1 (Pin No. 2 and/or 4) has to be connected to the vehicle chassis.

#### 7.4.1 Signal interface to the vehicle X1

Connector Set X1 ELFA2:

	Top entry	Side entry
		
Tyco No.	0-1103444-1	0-1103444-2
Siemens No.	A5E01068694	A5E01068702

Pin No.	Signal Name	Description
	<b>Power Supply</b>	
1	KL 30	Continuous power supply 24 V
2	KL 31	Power Supply Ground
3	KL 30	Continuous power supply 24 V (Redundancy)
4	KL 31	Power Supply Ground (Redundancy)
	<b>CAN Interface</b>	
8	CANH1	CAN1 interface High (DCAN)
9	CANL1	CAN1 interface Low (DCAN)
5	CANT1	Activation of termination CAN1
6	GND	KL 31 Signal Ground CAN1
12	CANH2	CAN2 interface High (High Speed CAN)
13	CANL2	CAN2 interface Low (High Speed CAN)
16	CANT2	Activation of termination CAN2
15	GND	KL 31 Signal Ground CAN2
	<b>Outputs</b>	
25	DOL 1	Reserve (binary, PWM and Frequency)
29	DOL 2	Reserve
	<b>Analog Inputs</b>	
7	AINP 1	Reserve
18	AINP 2	Reserve
10	TEMP EXT1	External temperature sensor Pt1000 analog input
14	TEMP EXT2	External temperature sensor Pt1000 analog input
17	GND	KL 31 Ground TEMP EXT, AINP
	<b>Digital Inputs</b>	
24	DIL 1	Reserve
28	DIL 2	Reserve
21	DIL 3	Reserve
32	DIL 4	Reserve
31	DIH 5	External Enable for IGBT Phase L4

20	DIH 6	External Enable for IGBT Phase L1-L3
27	KL 15	Ignition (Key On, Control signal of power supply)
30	GND	KL 31 Signal Ground IO's
	<b>Coding</b>	
19	BIN0	Input Coding Bit 0
22	BIN1	Input Coding Bit 1
26	BIN2	Input Coding Bit 2
11	BIN3	Input Coding Bit 3
23	GND	KL 31 Signal Ground Coding
DOL = Digital output low-active switches according to ground		
DIL = Digital input low-active 24 V internal		
DIH = Digital input high-active GND internal		
AINP = Analog Input 0 – 5 V		

### 7.4.2 Signal interface to motor/generator X2

Connector Set X2 ELFA2: Tyco No. 0-1103445-1 (Siemens No. A5E01068700):

Pin No.	Signal Name	Description
1	P15_ENC	Power supply for speed encoder 15V
7	ENCA	DIL input for speed encoder A
8	ENCB	DIL input for speed encoder B
9	ENCC	DIL input for speed encoder C
2	GND	Signal GND for speed encoder
5	GND	Signal GND for temperature measurement
3	T_MOT1	Motor temperature 1 (1k pullup resistance to voltage reference of the A/D inverter)
4	T_MOT2	Motor temperature 2 (1k pullup resistance to voltage reference of the A/D inverter)

### 7.4.3 Signal interface to other traction inverters

- To use electric motors with two winding systems the connector X9 is used for dual inverter operation (refer also to section 7.5.2)
- For more informations about this contact Siemens AG.

## 7.5 Power rating traction inverter

### 7.5.1 Absolute maximum ratings

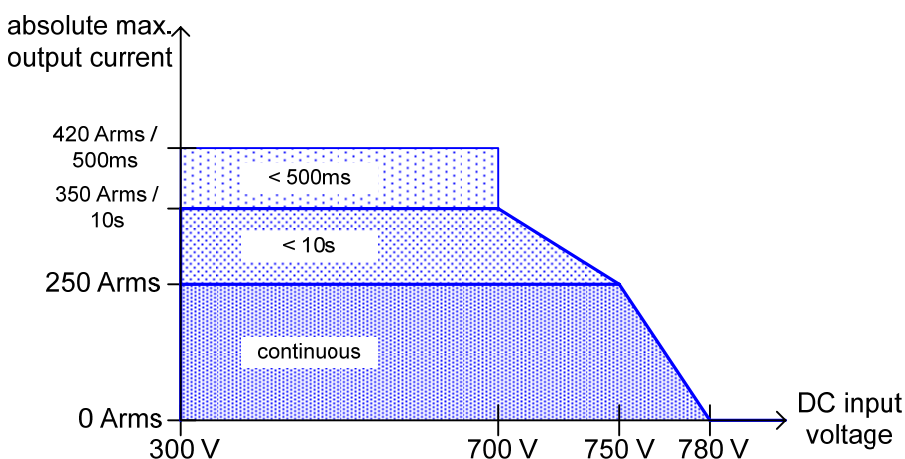
#### CAUTION

- Maximum ratings are those values beyond which device damage can occur. Maximum ratings applied to the device are individual stress limit values (not normal operating conditions) and are not valid simultaneously. If these limits are exceeded, device functional operation is not implied, damage may occur and reliability may be affected.
- Max. values depending on e.g. temperature model, lifetime expectation and pulse control factor.

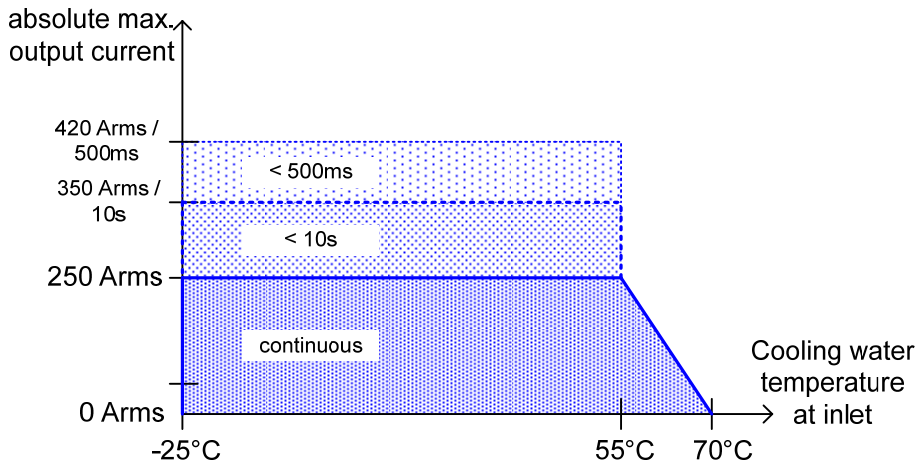
- Absolute maximum ratings:

Parameter	min	typ	max	Unit
Voltage range (pulse disable)				
continuous	0		800	VDC
5 times 1 min per hour	0		850	VDC
Over-voltage release			820	VDC
DC input voltage range	300	650	780	VDC
Input current continuous			250	ADC
Output current continuous			250	Arms
Output current (10s every 5 min)			350	Arms
Output current (500ms every 5 min)			420	Arms
Over current release			680	Apeak
Output frequency			1000	Hz
Switching frequency range	1		10	kHz
Uce-Switch Off Current (desaturation protection)	1000			A

- Absolute max. output current versus DC input voltage (depending on temperatures, lifetime expectation and pulse control factor):

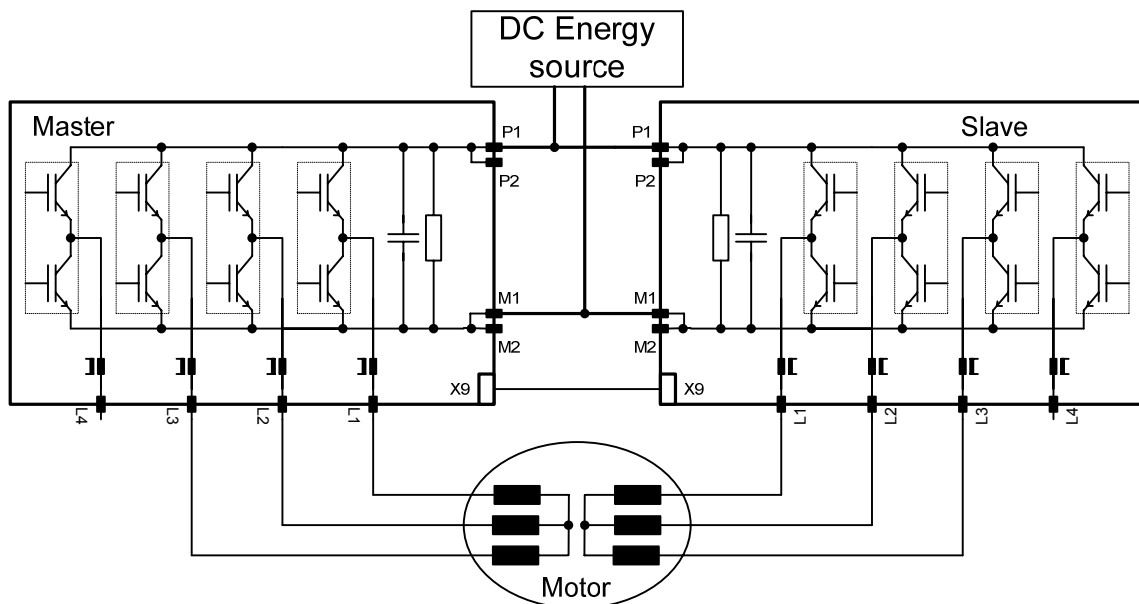


- Absolute max. output current versus cooling water temperature (depending on temperatures, lifetime expectation and pulse control factor):



## 7.5.2 Dual inverter operation

- For more informations about this contact Siemens AG.
- The following figure shows a typical dual inverter operation:



## 7.6 DC-link

- Aluminum electrolytic capacitors:

Parameter	Symbol	min	typ	max	Unit	Note
Total capacitance	$C_{ZK}$	1,6	2	2,4	mF	
Discharging resistor (between P1/P2 and M1/M2)	R		24		k $\Omega$	

**7.7 Power supply 12V / 24V**

- The 12V / 24V power supply is galvanically isolated from the high voltage part of the traction inverter.
- Characteristics power supply 12V/24V:

Parameter	Symbol	min	typ	max	Unit	Note
Input voltage, static	$U_{KL\_30}$	9		36	V	
Undervoltage release	$U_{KL\_30\_min}$		8		V	$\leq 400ms$
Time until undervoltage release		20			ms	Restart after voltage recovery
Ride-through interval		20			ms	$U_E = 9V$
Switch-in threshold	$U_{KL\_30\_on}$	8,5		9,0	V	
Switch-off threshold	$U_{KL\_30\_off}$	7,0		8,0	V	
Protection against polarity reversal	$U_{KL\_30\_max}$			- 28,2	V	
Recommended external fuse		5		8	A	For KL30
Recommended external fuse for 2 inverter parallel			8		A	Only 24V supply
Input power						
pulse disable	$P_{KL\_30\_pd}$		10		W	
typical operating point	$P_{KL\_30\_typ}$		16		W	Output 3x 250Arms
Input quiescent current	$I_{KL\_30\_off}$			2	mA	After keep alive

- Characteristics power supply 15V for speed encoder:

Parameter	Symbol	min	typ	max	Unit	Note
Supply current for speed encoder with 2 tracks	$I_{P15\_ENC}$			80	mA	
Supply current for speed encoder with 3 tracks	$I_{P15\_ENC}$			70	mA	

- Starting profile according ISO 16750-2:

Parameter	Value
Supply voltage for UN = 12 V: Functional status as defined in ISO 16750-1: - Level I - IV	Code C Class C
Supply voltage for UN = 24 V Functional status as defined in ISO 16750-1: - Level I-II: - Level III	Code F Class A Class C



## 8 Mechanical characteristics

Parameter	Note
Type of construction	Aluminum cooling/base plate with enclosure to protect the electrical components
Material (enclosure)	Housing: aluminum
Sealing	Combined dust/water/EMC sealing
Degree of protection acc. to ISO 20653 (all interfaces are connected correctly, all assembly openings closed correctly)	IPX7, IP6K9K, IPX6K

### 8.1 Dimensions / weight

- Approximately: 412 mm x 454 mm x 183 mm
- Weight: max. 30 kg
- For details refer to the respective “Dimension drawing” (refer to section 14.2).

### 8.2 Mechanical vibration test method (broad-band random)

- The mounting location of the inverter is “Mounting on the exterior / to frame” in accordance with ISO 16750-3. The vibration on sprung masses is random vibration induced by rough-road-driving. Failure mode is rupture due to fatigue.
- Requirements according to ISO 16750-3 Clause 4.1.2.7, Test VII.  
Test duration: 32 h each plane
- Values for frequency and power spectral density:

Frequency [Hz]	PSD [(m/s <sup>2</sup> ) <sup>2</sup> /Hz]
10	18
20	36
30	36
180	1
2000	1
r.m.s. acceleration 57,9 m/s <sup>2</sup>	

#### CAUTION

The traction inverter must not be mounted on or near the combustion engine.

### 8.3 Mechanical connections

- Mechanical connections for mounting refer to the respective “Dimension drawing” (refer to section 14.2).

#### CAUTION

If vibration dampeners are used to mount the traction inverter, the user has to check that no resonance sharpness does occur.

## 9 Environmental conditions

### 9.1 Ambient Conditions

#### CAUTION

- No forced air > 70°C around the traction inverter allowed.
- Exposure to strong solar radiation on the traction inverter is not allowed.

Parameter	min	max	Unit
Storage- and transport temperature (without coolant)	-40	90	°C
Ambient temperature for operation			
without power reduction	-40	70	°C
with power reduction	70	85	°C
Operating altitude (above sea level)		2500	m
Parameter	Value		
Climatic stressing in operation	IEC 60721-3-5 Class 5K2		
Air pollution in operation	IEC 60721-3-5 Class 5C3		

### 9.2 Chemical loads

The traction inverter is designed to have best resistance against chemical loads in automotive environment. Nevertheless, because of the multitude of chemical loads specific types have to be discussed with Siemens AG.

### 10 Cooling circuit

All coolant connections are tube stems for connecting the coolant hoses directly. The hoses are fixed using hose clamps. The rated diameter of the hoses has to be chosen according to the diameter of the tube stems shown in the respective "dimension drawing" (refer to section 14.2).

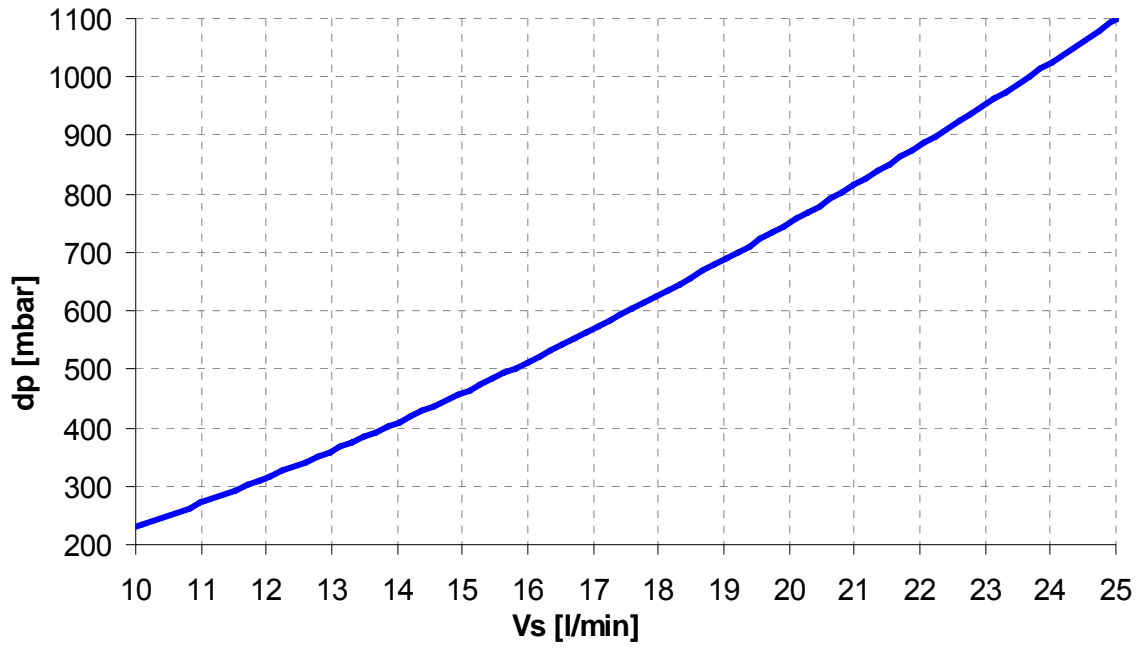
<b>CAUTION</b>
<ul style="list-style-type: none"> <li>• Proper venting has to be realized within the cooling system.</li> <li>• The contact of aluminium with copper and/or zinc (e.g. in the cooling circuit) is forbidden.</li> <li>• Cooling with seawater is forbidden.</li> <li>• Operation without the water cooling system is not permissible, even at low temperatures, i.e. leakage or interruption of water flow have to be detected and the inverter need to be turned off.</li> <li>• To avoid damage of the traction inverter a pressure switch has to be provided in the cooling system and its actual state has to be reported to the Siemens system.</li> </ul>

The cooling performance of the pump and the radiator must satisfy following key data for the traction inverter:

Parameter	min	typ	max	Unit
Cooling-medium temperature for operation				
without power reduction	-25		55	°C
with power reduction (low temperature)	-40		-25	°C
with power reduction (high temperature)	55		70	°C
Cooling water temperature	-40		70	°C
Cooling flow per unit time*	10		25	l/min
Cooling flow per unit time for rated conditions	15			l/min
Operating pressure			5	bar
Testing pressure			7,5	bar
Volume cooling-medium in cooling-plate		0,27		l
Temperature difference at rated conditions between cooling water inlet and discharge			5	K
Parameter	Value			
Cooling medium: water + anti-freeze	Water: <ul style="list-style-type: none"> <li>• free of oil, suspended particles and salts causing hardness</li> <li>• pH value 6.5 - 8 at 20°C</li> <li>• chloride: ≤ 50 mg/l</li> <li>• sulfate: ≤ 50 mg/l</li> <li>• dissolved solids, total: ≤ 340 mg/l</li> <li>• sum of alkaloids of soil: &lt; 2,5 mmol/l (former: total hardness)</li> <li>• max. particle size &lt; 100µm</li> </ul> Anti-freeze: <ul style="list-style-type: none"> <li>• Glysantin 9319 (BASF) or Antifrogen N (Clariant)</li> </ul>			
Cooling medium mixture	up to -25 °C: 40 % anti-freeze and 60 % water up to -35°C: 50 % anti-freeze and 50 % water up to -40°C: 56 % anti-freeze and 44 % water			

\* The thermal resistance as well as the pressure drop (see figure below) of the heatsink depend on the flow rate. The required flow rate has to be discussed according the customers requirement regarding current, cooling temperature as well as lifetime requirements.

- Pressure drop over flow rate of cooling-medium (50% AFN / 50% water / 50°C):



## 11 Electromagnetic compatibility (EMC)

### NOTICE

- The control cables must be laid separately from the power cables. Carry out the connections as shown in the installation section in this manual, to prevent inductive and capacitive interference from affecting the correct function of the system.
- E1-type approval - if available - will be marked on the rating plate of the inverter.

## 12 Protective measures



### 12.1 Insulation

#### Protection against direct contact

The degree of protection of the traction inverter housing is designed according to chapter 8. Direct contact with live parts is not possible when the traction inverter is installed and connected correctly.

#### Protection against indirect contact

The power stage of the traction inverter is galvanically insulated against the vehicle chassis and the signal electronics.

	 <b>WARNING</b>
	<ul style="list-style-type: none"> <li>• The inverter must always be connected to the vehicle chassis using the ground / protective earth connection.</li> <li>• Pin No. 2 and/or 4 (KL31) of connector X1 has to be connected to the vehicle chassis.</li> <li>• A ground fault monitoring for the DC-Link has to be implemented.</li> </ul>

#### Insulation test (type test)

Power stage of the traction inverter against signal electronics and vehicle chassis.

Voltage (to all relevant inputs of the DUT): 2,5 kV AC / 50 Hz

Test duration: 60 s ± 10 %.

#### Insulation test (routine test)

Power stage of the traction inverter against signal electronics and vehicle chassis.

Voltage (to all relevant inputs of the DUT): 3,6 kV DC

Test duration: 10 s ± 10 %.

#### Insulation resistance

Power stage of the traction inverter against signal electronics and vehicle chassis.

Refer to "Measurement insulation resistance ELFA2" (refer to section 14.2).

Product numbers	Product Name	Insulation resistance
A5E02503560	ELFA2 DC4-650WM	≥ 30 MΩ
A5E02049710	ELFA2 DC4-650WM-2	
A5E00468614	ELFA2 DC4-650WM-C	2,35 MΩ

#### Insulation co-ordination

Insulation co-ordination according to EN 50124-1



#### Rating plates / Warning labels

Each component is fitted with a rating plate and warning labels, their positions are marked on the respective "dimension drawing" (refer to section 14.2).

#### Discharging

The internal discharge resistor (refer to section 7.6) discharges the internal DC-Link capacitor in less than 3 min down to 60V.

## 12.2 Protection concept

	 <b>WARNING</b>
	<ul style="list-style-type: none"> <li>The drive system has to handle every kind of DC-Link short-circuit.</li> </ul>

### Sensors

- Current sensors are provided for the phases L1, L2, L3 and L4:  
Current transducers with measurable current up to 350 A rms / 680 A peak
- Bus voltage measurement with measurable voltage up to 1000 Volts
- Heatsink temperature with measurable temperature: -40°C .. +90°C

### Phase current protection

Overcurrent protection (hardware): A hardware comparator verifies the peak current of the traction inverter phases and in case it exceeds the maximum measurable current of the current sensor the LCA will generate a “pulse disable” for the IGBTs.

Overcurrent protection (software): The controller verifies the peak current of the traction inverter phases and in case it exceeds a maximum value (value to be discussed with Siemens AG), it will generate a “pulse disable” for the IGBT's (e.g.: PWR: all 6 IGBT's are switched off; 4. Phase: upper/lower IGBT of 4. Phase is switched off).

### Temperature monitoring

The traction inverter has a temperature sensor close to the IGBT module. The generated signal is evaluated by the drive control module. When the permissible temperature range is exceeded, then:

The power is reduced (de-rating), and if necessary, the equipment will shut down.

### Control-independent protective functions

The following protective functions are implemented in the traction inverter (independent of the motor control board (MCB), drive control module):

- Transient overvoltages are smoothed (load fluctuations) by the DC link capacitors.
- Discharge of the DC link capacitors via the continuous discharge resistors in the powered-down condition.
- Protection against IGBT de-saturation.

## 12.3 Fire protection measures

- High degree of protection (refer to section 8).
- Aluminium housing
- All used materials have the following characteristics:
  - low flammability
  - fire retardant





## 14 Attachment to user information

### 14.1 Tool and material list

- Magnetic screw driver or wrench for hexagon-head bolt M10
- Wrench for EMC cable glands M25 (power cable connection).
- Wrench for EMC cable glands M20 and M16 (signal cable connection).
- Torx screwdriver (T20) for the terminal box covers and the signal connectors.

### 14.2 Attachments

Relevant technical documentation:

Item	Designation	Drawing number	Respective Product
1	Measurement insulation resistance ELFA2	A5E02531131A	
2	Return Information ELFA	A5E02531131D	
3	Dimension drawing	A5E02503560C	A5E02503560 A5E02049710 A5E00468614

### 14.3 Change Index

Edition	Short description of changes	Page	Date
AA	First valid edition		2007-05-09
AB	Amendments for correct use	12,19	2007-08-13
AC	Adaptation of insulation resistance	22	2007-09-07
AD	Introduction prototype ELFA2 DC4-650WM	8-22	2008-03-18
AE	New version including technical data from "customer spec"	All	2009-09-02
AF	New ELFA2 DC4-650WM A5E02503560 added	7,28,29	2010-05-26
AG	New technical data added, ELFA2 DC4-650WM-1 deleted	all	2011-02-03
AH	New technical data added	24, 27, 32	2011-03-23