HEINZMANN®
Electric Drives

User Manual V 1.3

ACD xxxx Drive
Motor controller for
brushless permanentmagnet Motor
Generation 1
1 INTRODUCTION

1.1 ABOUT AC DRIVE DOCUMENTATION

1.1.1 THIS VERSION
This version replaces all previous versions of this document. We have made every effort to ensure this document is complete and accurate at the time of printing. In accordance with our policy of continuing product improvement, all data in this document is subject to change or correction without prior notice.

1.1.2 SCOPE
This manual presents instructions, guidelines, diagram and other information relevant for installation and maintaining the AC Drive in an electrically powered vehicle utilizing the discrete I/O:s an/or CAN Bus and CANopen protocol for communications and control.

1.1.3 WARNING, CAUTION AND INFORMATION NOTICES
Special attention must be paid to the information presented in Warning, Caution and Information notices when they appear in this manual. Examples of Caution, Warning and Information notices along with an explanation of their purposes follow.

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

- **CAUTION**
  A Caution informs the user of a hazard or potential hazard that could result in injury or damage to the equipment if the precautions or instructions given in the caution notice are not observed.

- **Information Box**
  An information Box contains supplemental information or reference to supplemental information on a topic.

- **Stop Box**
  Stop Box highlights important conceptual or procedural details that must be understood and applied in order to successfully use the product.

1.1.4 RELATED DOCUMENTS
Object Dictionary. The Object Dictionary provides important information about CANopen communication with the AC Drive.
1.2 ABOUT THE AC DRIVE

1.2.1 PERSONAL SAFETY

HEINZMANN provides this and other manuals to assist manufacturers in using the AC Drive in a correct, efficient and safe manner. Manufacturers must insure that all persons responsible for the design and use of equipment employing the AC Drive have the proper professional skill and apparatus knowledge.

**WARNING**
The high power levels and high torque available from a motor, AC Drive combination can cause severe or fatal injury.

**CAUTION**
The AC Drive is intended for connection only to DC battery power sources and for use with low voltage asynchronous motors. Always verify before installation that the AC Drive model is correct for the vehicle's battery supply voltage. The DC Supply nominal voltage is stated on a label on the cover of each AC Drive.

1.2.2 OEM'S RESPONSIBILITY

Our AC Drive products are intended for controlling motors in battery powered electric vehicles. These drives are supplied to original equipment manufacturers (OEMs) for incorporation into their vehicles and vehicle control systems.

OEM's are responsible for ensuring that AC Drives are used for their intended purpose only, safe function of the system and for compliance with all applicable regulations. Responsibility for the safe functioning of the system reverts to the owner or user in all cases.

1.2.3 TECHNICAL SUPPORT

For additional information on any topic covered in this document, or for additional information or application assistance contact HEINZMANN

1.2.4 REPAIR

Repair and testing of the AC Drive is available at: HEINZMANN
1.3 **PRODUCT VARIANTS**

1.3.1 **CONFIGURATIONS**

The AC Drive is manufactured in the following configuration.

- Conduction cooled models (see Figure 1) with a flat heat sink and mounting surface that transfers heat into the surrounding vehicle structure by conduction.
- Volt range: 24/36/48/80 V.
- Full functional control via discrete I/O:s or via CANbus.
- Combinations are also possible.
- Various I/O configurations for interfacing to the vehicle system.

1.3.2 **AC DRIVE IDENTIFICATION LABEL**

A label containing pertinent product identification information is attached to the AC Drive cover next to the B+ terminal post. The product label fields relevant to product identification are described below. See Figure 1 for placement and Figure 2 for a label appearance.

![Controller technical data](image)

Figure 2: AC Drive Product Identification Label
1.4 **STANDARD FEATURES OF THE AC DRIVE**

The AC Drive incorporates a number of features and capabilities important to the electric vehicle designer including:

- Modern AC flux-vector control techniques for improved performance and operating efficiency.
- A family of drives covering a wide range of power outputs and battery voltages.
- Programmable to match the characteristics of compatible induction or brushless PM motors.
- Designed for the environment of the electrically powered vehicle.
- Closed loop speed regulator provides unequalled vehicle speed control when moving and neutral braking for maintaining position when stopped.
- Full four-quadrant operation - drive can directly accelerate or decelerate the motor in both forward and reverse directions (no direction contactors required).
- Regenerates dynamic braking energy down to zero speed.
- Fully protected against under voltage, over voltage, over current and reverse polarity and over temperature conditions.
- Built-in neutral start (also called high pedal) protection prevents vehicle motion on startup until drive sees a zero speed command.
- CAN bus interface for safe and reliable networking in a vehicle control system.
- Extended I/O:s for standalone applications.
- Total software configurability eliminates all operator adjustments and assures absolutely reproducible performance of identically configured AC Drives.
- All heat generating components mounted on a massive heatsink whose temperature is monitored.
- Error/fault monitoring software implements necessary measures to prevent unsafe operation if problems exist.
- Warning/error codes and an error log provide informative and timely information for diagnosis and elimination of problems.
- Total user control over acceleration, braking and speed.
2 OVERVIEW OF A DRIVE SYSTEM

In a typical system (see Figure 3), one AC Drive directs the motion of a traction motor coupled to the drive wheels. AC Drives convert DC power from the vehicle’s battery to three phase AC power at the frequencies and currents necessary to drive their respective motors as commanded.

The main contactor, under control of the AC Drive, supplies battery power to the power conversion section and removes battery power under certain error and fault conditions. An external fuse protects the drive and cables against short circuit faults in the power conversion section.

An internal PTC (Positive Temperature Coefficient) resistance limits inrush current to a bank of filter capacitors when power is first turned on via the key start.

The key start contactor controls application of power to the control electronics section of the AC Drive.

The motor provides feedback of its speed, direction and temperature to the AC Drive for control and monitoring purposes. A speed sensor is integrated into the motor produces speed and direction feedback signals and a temperature sensor (PTC resistance) embedded in the stator winding provides an indication of motor temperature.
The AC Drive can be used as a standalone unit with all I/O signals (frw/rev, speed etc.) connected direct to the AC Drive. Alternatively can the AC Drive be controlled via a truck controller and CANBus.

The truck controller, based on input from operator controls and other criteria, transmits speed, braking and other commands to the AC Drives over the CAN Bus. The truck controller regularly monitors drive status and initiates corrective action upon recognition of a warning/error condition.

When a fault/error condition warrants, the truck controller may open the main contactor, removing battery power from the AC Drive power stage.

## 2.1 Principles of Operation

### 2.1.1 Functional Description

Figure 4 shows a functional block diagram of the AC Drive including the principal drive inputs and outputs. Some SuperDrive functions are executed by dedicated hardware, while others are implemented mainly in software. The following paragraphs provide additional details on each functional block.

![Figure 4: AC Drive Block Diagram](image-url)
2.1.2 CAN INTERFACE

The CAN Interface manages communications between the AC Drive and the CAN Bus. The CAN controller provides the electrical interface and within the software the CANopen protocol is handled.

2.1.3 SPEED CONTROL

The Speed Control accepts speed set points (Command Speed) as input and produces torque commands (Torque Current) as output. It can function as a closed loop, proportional or proportional plus integral, speed controller with feedback provided by the sensor bearing. It includes provisions for limiting torque both in amplitude and derivative. It is also possible to use advanced speed ramping functionality within the Speed Control block. The Speed Control is implemented in software, with operating characteristics set by programmable parameters.

2.1.4 CURRENT CONTROL AND SPWM-sym

The dq-plane implemented current controller (so called vector control) controls the magnetization current and the torque producing current independently of each other. The software implemented Current Control is able to compensate for temperature and frequency related changes in motor winding impedance as well as variations in the DC-supply voltage, thereby providing precise control of motor flux and torque over a wide range of operating conditions. The Current Control computes the required motor voltage, which is then realized by SPWM-sym (Sinusoidal Pulse Width Modulation with summarization). The output from the SPWM-sym block is the MOSFET gate pulses.

2.1.5 POWER CONVERSION SECTION

The principal drive output, a variable frequency, variable amplitude, three phase current, is produced by the Power Conversion section from a DC power source. Figure 5 shows the general circuit configuration. Depending on its current rating, an AC Drive may employ more or less transistors than illustrated in Figure 5. During braking, regenerated energy from the motor is returned to the battery.

All power components are mounted and thermally bonded to a large heatsink that forms one surface of the drive. Heatsink temperature and DC supply voltage are sensed and monitored for control and protection purposes.

Utilizing efficient MOSFET power transistors, the Power Conversion section amplifies three PWM (Pulse Width Modulated) current commands supplied by the Current Regulator producing three PWM voltages (see Figure 6). These PWM voltage waveforms, when applied to the inductance of the stator, produce currents in the motor, which approximate sine waves.
During braking, the rotor runs at higher speed than the speed of the synchronous flux vector and the motor functions as a generator, supplying power to the battery. The change from motor to generator is smooth and instant when rotor speed exceeds synchronous speed. The AC Drive supplies a magnetizing current at the proper frequency for optimum regeneration performance.
The generated power is dependent on the slip (which the AC Drive controls). The transistors function as a 6-pulse rectifier (see Figure 7), converting the 3-phase AC current to DC-current that charges the battery.

**Figure 7: Current Flow During Regeneration**

### 2.1.6 Speed Sensor Interface

The Speed Sensor Interface converts the quadrature signal outputs from a sensor to digital speed and direction numbers for use by the drive and system functions. Alternatively, an analog sin/cos output sensor can be used.

### 2.1.7 Logic Power

The Logic Power Supply converts battery voltage applied via the KEY START input to the voltages required internally.
2.2 SAFETY AND PROTECTIVE FUNCTIONS

2.2.1 GENERAL

The AC Drive performs extensive checks and monitoring to protect the motor, drive and vehicle from damage and prevent operation under unsafe conditions. Two response levels are employed: warning level and error level. Errors are serious problems that prohibit continued operation of the AC Drive. Less serious problems that permit continued AC Drive operation, often at reduced capacity, produce warnings.

For some items monitored, the AC Drive provides a two stage response including a warning when the item is approaching its safe operating limit and an error response when the safe operating limit is exceeded.

A complete Troubleshooting guide for the AC Drive is present in section 6 “Troubleshooting Guide”

2.2.2 ERRORS

When an error is detected, the AC Drive operating software immediately stops motion then shuts down the drive’s power output to the motor. Concurrently, the AC Drive’s internal error status is updated to reflect the error code(s) for existing error conditions and if the system is CAN based, an emergency message containing the new error status is sent. The AC Drive’s status indicator changes from steady on to flashing.

An inherent safety feature of the AC Drive is that no single component failure can cause a run away condition in the controlled motor. Since DC current produces no torque in an AC Motor, a shorted output transistor in the Power Conversion section causes the motor to slow down or stop.

2.2.3 WARNINGS

The AC Drive’s internal warning status is updated to reflect the code(s) for existing warning conditions. Operating with active warning conditions does not affect the AC Drive’s status indicator, which remains in steady on condition. When the root cause of a warning is removed, the AC Drive automatically removes any reduced capacity restriction related to the warning condition.
2.3  **AC Drive Communications**

2.3.1  **I/O Based Control**

All I/O signals as switches, potentiometers, contactors etc. are connected directly to the connector K1. Commands are then executed from the I/O information. The CANbus may be used for downloading new SW and for service purposes.

2.3.2  **CAN Based Control**

On a truck CAN network the truck controller functions as the master and AC Drives are slaves. Commands, motion variables and parameters exchanged between a truck controller and an AC Drive are embedded in CANopen communication objects. In the CANopen Communications protocol implemented in the AC DRIVE, the following five types of objects (messages) are utilized:

<table>
<thead>
<tr>
<th>OBJECT (MESSAGE) TYPE</th>
<th>PURPOSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Data Object (SDO)</td>
<td>Exchange of non-real time data and control.</td>
</tr>
<tr>
<td>Process Data Object (PDO)</td>
<td>Exchange of real time data and control.</td>
</tr>
<tr>
<td>Synchronisation Object (SYNC)</td>
<td>Broadcast periodically by the master to all slaves to synchronize network devices and processes with the master.</td>
</tr>
<tr>
<td>Network Management (NMT)</td>
<td>Transmitted by the master to control network boot up, initialization and state transitions. Network management messages may be directed to individual devices or broadcast to all network nodes.</td>
</tr>
<tr>
<td>Emergency (EMCY)</td>
<td>Transmitted by slaves to signal internal error conditions to the master.</td>
</tr>
</tbody>
</table>

The AC Drives may be configured to utilize the periodic SYNC message from the truck controller (or other device on the CAN Bus) by which the AC Drive confirms that the truck controller and CAN communications are functional. Upon reception of the SYNC object, the AC Drive initiates the sending of a Transmit PDO containing a summary of its operating state. The AC Drive can also be configured so that the Transmit PDO is initiated by the periodic Receive PDO. Then there is no need of a periodic SYNC object.

Each AC Drive requires a periodic Receive PDO containing motion and related control variables. The AC Drive can be configured to use one or two Transmit/Receive PDOS.

Messages intended for specific devices on the CAN network contain a COB-ID (Communications Object - Identifier) field which identifies the target node (device) for the message. Each AC Drive on the Bus must have a unique ID.

A combination of some CAN based control and some I/O based control is also possible.
3 INSTALLATION

3.1 INTRODUCTION

This chapter presents instructions and guidelines for installing an AC Drive in a vehicle. The information is general in nature. The actual procedure for mounting the AC Drive in a specific vehicle may vary from what is presented here or include additional steps.

We offer the following guidelines and precautions regarding mounting location for the AC Drive:

- AC Drive’s cover provides a measure of protection from liquids and particles dripping, splashing or spraying onto the unit; however, the AC Drive is not environmentally sealed. It should not be located in a place where it is subjected to liquids under high pressure.
- The protection class, IP54, is only valid when the mating connector, K1, is inserted.
- The AC Drive LED status indicator provides useful diagnostic information for troubleshooting of some vehicle problems. The troubleshooting process can be facilitated if this indicator is visible.
- High power levels are available at each of the connection posts. Therefore they should be protected from accidental short circuits.

3.2 COOLING REQUIREMENTS

A massive heatsink comprising the entire bottom surface of the AC Drive transfers heat from the Power Conversion section components into the body of the vehicle. **Drives operating at or near their continuous power output (1 hour rating) require different thermal resistance depending on AC DRIVE size for dissipation of heat to maintain heat sink temperature in the safe operating zone.**

The AC Drive is cooled by the surface contact to the vehicle body. Observe demands to surface roughness and surface flatness where the AC Drive is mounted to the vehicle body. Apply thermal grease at the AC Drive before mounting for best cooling effect, see also Surface demands.

For thermal resistance demands, see Operating environment.

3.3 CLEARANCES FOR ACCESS AND AIR CIRCULATION

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

For additional details on surface roughness and flatness demands for AC Drive see Table 9. Apply thermal grease at the AC Drive before assembly.
3.4 ORIENTATION

The AC Drive is not to be orientated upside down; either horizontal or vertical mounting is acceptable, although a horizontally mounted unit tolerates higher levels of mechanical shock than a vertically mounted unit. Consideration should be given to visibility of the on-board status indicator for maintenance purposes. High power levels are available at each of the connection posts; therefore they should be protected from accidental short circuits.

For EMC and ESD purposes, we strongly recommend that both the AC Drive and the Heatsink and the houses of the motors are connected to the chassis.

3.5 TOOLS AND EQUIPMENT REQUIRED

The depth of thread in the vehicle body should be at least 8 mm. The following tools and hardware are recommended for mounting an AC Drive:

- Four (4) MC6S M6 x L 8.8 fzb DIN 912)/MRT M6 x L 8.8 fzb, T30 (DIN 7985) bolts or equivalent (1/4 UNC) bolts, (pos 1).
- Four (4) washer BRB 8.8 HB 200 fzb (DIN 125A), (12 x 6.4 x 1.6). Pos 2.
- Heatsink thickness see Dimensions at page 41.
- Thermal grease Electrolube HTC or Dow Corning 340

3.6 MOUNTING AC DRIVE

The AC Drive is secured to the vehicle body by following procedure.

1. Verify that the item number for the unit is correct for the application.
2. Apply thermal grease (OEM supplied) at the AC Drive surface, mounted onto the vehicle.
3. Install AC Drive to the vehicle body Figure 8 and tighten selected bolts (OEM supplied) slightly to the vehicle body.
4. Tighten the bolts from up left to right down to 6 Nm ± 0.3 Nm.

Figure 8: Installing AC Drive
3.7 **Motor and Battery Connections**

**Table 2** provides a description of the five terminal post connections on the AC Drive.

<table>
<thead>
<tr>
<th>Terminal</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>B+</td>
<td>Battery positive termination. (External battery fuse is required).</td>
</tr>
<tr>
<td>B-</td>
<td>Battery negative termination</td>
</tr>
<tr>
<td>U, V, W</td>
<td>Three-phase motor phase termination.</td>
</tr>
</tbody>
</table>

**Table 2. Motor and battery connections.**

**CAUTION**

Ring lugs for motor and battery connections must be adequately rated to carry motor and battery currents; otherwise, overheating may result.

Crimp ring lugs onto ends of cables, then secure the lugs to terminal posts using bolts M6 x L, lock washer and washer.

**Figure 9** shows recommended connections to terminal posts. Use a torque wrench with 10 mm socket. Tighten bolts to 7,5 ± 0,5 Nm.

Choose a suitable bolt length regarding to the thread depth.

Thread depth \( L_T = 10 \pm 2/ -1 \text{ mm} \).

The following equipment is required:

- 5x Bolt M6S M6 x L 8.8 fzb (DIN931/933 or other M6 type of bolt) for battery and motor connection (for L, see above).
- 5x Lock washer (DIN 127B). Dim. 12.2 x 6.5 x 1.6 mm or 1/4” ID.
- 5x Washer BRB 8.8 HB 200fzb (DIN 125A). Dim. 12 x 6.4 x 1.6mm or 1/4” ID.
- 5x Ring lugs with 6.5 mm hole diameter for battery and motor connection.
- 10 mm Box wrench.

It is recommended that a fuse is installed between the battery and + terminals on the AC Drive. The fuse protects the drive and power distribution circuit in the event of a short circuit fault in the power conversion section. Note that the fuse is not intended to protect the AC Drive or motor against overloads. Since the AC Drive employs a software controlled closed
loop current regulator, motor overloads, drive overloads and shorts in the motor are normally
detected and managed by the AC Drive and typically do not cause the fuse to blow.
The fuse should be sized based on the AC Drive’s power output (2 min. rating). Compute DC
input current as follows:

\[ I_{DC\_IN} = \frac{power output[kVA](2\ min.\ rating) \times 1000}{VBATT} \]

Select a fuse with rating and time delay characteristics which will carry \( I_{DC\_IN} \) indefinitely, but
blow within 2 - 3 seconds for \( 2 \times I_{DC\_IN} \).
3.8 CONTROL AND I/O CONNECTIONS

The connector (Plug AMPseal 23P 770680-1, Contact 770854-1) provides the electrical interface for all control and I/O connections to the APS 2. Refer to Table 3 for a description of the control and I/O signals.

<table>
<thead>
<tr>
<th>Digital INPUT</th>
<th>Low &lt; 2V; High&gt;8V; Max B+, impedance 8,1 kΩ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital_IN_1 – DIGITAL_IN_6</td>
<td></td>
</tr>
<tr>
<td>Analog INPUT</td>
<td>0 – 6,45V – impedance 43 kOhm</td>
</tr>
<tr>
<td>OPEN DRAIN OUTPUT</td>
<td>Open Drain Output</td>
</tr>
<tr>
<td></td>
<td>sinks 1A cont.; 2A peak, with current measurement.</td>
</tr>
<tr>
<td></td>
<td>For inductive load, an external free wheel diode shall used.</td>
</tr>
<tr>
<td></td>
<td>The output is a PWM Controlled or ON/OFF</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pin-No.</th>
<th>Type</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Input</td>
<td>KEY_IN</td>
<td>KEY START supplies battery voltage to the AC Drive for its internal processor and other functions. Applying battery power initiates the drive power up sequence. This input should be fused (max 1 A) for protection. Protected against reverse polarity. Power = 15 W</td>
</tr>
<tr>
<td>2</td>
<td>Output</td>
<td>OPEN-DRAIN_1</td>
<td>PARKING BRAKE (max 1 A)</td>
</tr>
<tr>
<td>3</td>
<td>Output</td>
<td>SENSOR_SUPPLY</td>
<td>Voltage supply for external sensors and Potentiometer 5 V DC; 50 mA max.</td>
</tr>
<tr>
<td>4</td>
<td>Output</td>
<td>GND</td>
<td>Ground reference for external sensors. (Not B+ protected)</td>
</tr>
<tr>
<td>5</td>
<td>Input</td>
<td>ENCODER_1</td>
<td>Motor feedback sensor CH_1 Input</td>
</tr>
<tr>
<td>6</td>
<td>Input</td>
<td>ENCODER_2</td>
<td>Motor feedback sensor CH_2 Input</td>
</tr>
<tr>
<td>7</td>
<td>Input</td>
<td>ANALOG_IN_2</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>CAN_GND</td>
<td>Ground reference for CAN</td>
</tr>
<tr>
<td>9</td>
<td>Input</td>
<td>ANALOG_IN_1</td>
<td>Potentiometer for Speed or Torque</td>
</tr>
<tr>
<td>10</td>
<td>Input</td>
<td>ENCODER_4</td>
<td>Not Connected</td>
</tr>
<tr>
<td>11</td>
<td>Input</td>
<td>ENCODER_3</td>
<td>Not Connected</td>
</tr>
<tr>
<td>12</td>
<td>Input</td>
<td>DIGITAL_IN_5</td>
<td>SET CAN Node ID (LSB)</td>
</tr>
<tr>
<td>13</td>
<td>Input</td>
<td>DIGITAL_IN_3</td>
<td>Switch FORWARD / REVERSE</td>
</tr>
<tr>
<td>14</td>
<td>Input</td>
<td>n.c</td>
<td>n.c</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>-------</td>
<td>--------------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>15</td>
<td>Output</td>
<td>CAN_L</td>
<td>CAN Bus low</td>
</tr>
<tr>
<td>16</td>
<td>Output</td>
<td>MOTOR TEMP</td>
<td>Temperature Sensor KTY 84-130 (not B+ protected)</td>
</tr>
<tr>
<td>17</td>
<td>Input</td>
<td>DIGITAL_IN_4</td>
<td>Max. FORWARD SPEED 1 / 2</td>
</tr>
<tr>
<td>18</td>
<td>Output</td>
<td>OPEN-DRAIN_2</td>
<td>WARNING / ERRORS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(max 1 A)</td>
</tr>
<tr>
<td>19</td>
<td>Input</td>
<td>DIGITAL_IN_1</td>
<td>ENPO (Enable Power Output)</td>
</tr>
<tr>
<td>20</td>
<td>Input</td>
<td>DIGITAL_IN_6</td>
<td>SET CAN Node ID (MSB) or</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Forward Speed 3 / 4</td>
</tr>
<tr>
<td>21</td>
<td>Output</td>
<td>OPEN-DRAIN_3</td>
<td>n.c</td>
</tr>
<tr>
<td>22</td>
<td>Output</td>
<td>OPEN-DRAIN_4</td>
<td>n.c</td>
</tr>
<tr>
<td>23</td>
<td>Output</td>
<td>CAN_H</td>
<td>CAN Bus high</td>
</tr>
</tbody>
</table>

*Table 3: Interface Connector K1 (AMP seal) Inputs and Outputs*

*Figure 10: Mating connector pin numbering (wiring side view)*
### 3.8.1 Assigning Multiple CAN Node Addresses

This feature enables from 1 to 4 ACD controllers on a single CAN Bus to have different CAN Bus Node addresses. Two digital inputs on each controller (PIN 12 & 20) are used to assign each controller’s address as follows:

**Valid in software-version: 69A21911C11-04.epf**

<table>
<thead>
<tr>
<th>CAN Node ID</th>
<th>Hardware ID</th>
<th>Connect Controller DI5 (PIN 12) to:</th>
<th>Connect Controller DI6 (PIN 20) to</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0</td>
<td>N.C</td>
<td>N.C</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>Battery –</td>
<td>Battery –</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>KEY_IN (PIN1)</td>
<td>Battery –</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>Battery –</td>
<td>KEY_IN (PIN1)</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>KEY_IN (PIN1)</td>
<td>KEY_IN (PIN1)</td>
</tr>
</tbody>
</table>

### 3.8.2 Parking Brake (OPEN_DRAIN_1)

Note: This parking brake control function is not available when operating the controller remotely using PDO Communications. In case, the vehicle master controller controls the OPEN_DRAIN_1 directly.
3.8.2 Key Start Input

The Key Start input (see Table 3 and Figure 3) supplies battery voltage to the AC Drive for its internal processor and other functions. The vehicle start key generally controls power to the Key Start input.

Fuse F2, should be sized according to the number of AC Drives and to protect the cable area in the circuit (recommended fuse size max 10A) and the current consumption of the Key Start input.

3.8.3 Motor Speed Sensor

The AC Drive can handle speed signals from analog or digital encoders. It provides speed and direction feedback for the AC Drive. Only one type of encoder input is available and the correct HW setup has to be chosen for each specific application.

An analog encoder (sin/cos) with two or three phases can be used. The two phase encoder has 90 degrees phase shift between the channels and the three phase has 120 degrees phase shift.

The sensor bearing is a typical example of a sensor integrated into the motor. It provides speed and direction feedback for the AC Drive. The standard sensor bearing produces a two-phase square wave output (Example SKF P/N 6206/VU1028 gives 64 pulses/revolution per phase).

Other pulse rates in the range 32 - 160 p/r can be selected in the Software. (Parameter is accessible via CANopen).

<table>
<thead>
<tr>
<th>K1 Connector Pin-No.</th>
<th>Signal name</th>
<th>Wire Color</th>
<th>Motor Side AMP Pin No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Power supply for Encoder (+5V DC)</td>
<td>green</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>Encoder GND</td>
<td>yellow</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>Encoder CH 1 (cos)</td>
<td>brown (^1)</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Encoder Ch 2 (sin)</td>
<td>rose (^1)</td>
<td>3</td>
</tr>
</tbody>
</table>

\(^1\) These two wires are motor depending. If the motor does not turn (i.e. oscillates around zero speed) at the first start up, these two wires have to be swapped. If the rotation direction is not correct, the SW parameter bit Inverted Rotation Direction in Application Setup Word (2020h:10) shall be set.

To minimize the possibility of electrical noise coupling into encoder lines, avoid routing encoder cables next to conductors carrying high currents or high current pulses. Noise immunity may also be improved by using twisted conductor cable for encoder to drive connections.

Contact the motor manufacturer to get the correct wiring; otherwise the characteristics for the sensor will be changed or the sensor could be damaged. There can be other connectors at motor side depending on OEM.
3.8.4 TEMPERATURE SENSOR

A temperature sensor with positive temperature coefficient (Philips P/N KTY 84-150) embedded in the motor winding (by the motor manufacturer) provides a means for the AC Drive to monitor motor temperature. Table 5 lists the colour coding and signal names for the standard motor temperature sensor.

![Characteristics of KTY-84](image)

### Table 5: Standard Motor Temperature Sensor Wiring Color Codes

<table>
<thead>
<tr>
<th>K1 Connector Pin-No.</th>
<th>Signal name</th>
<th>Sensor</th>
<th>Wire Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>MOTOR Temperatur</td>
<td>KTY +</td>
<td>Red</td>
</tr>
<tr>
<td>4</td>
<td>GND</td>
<td>KTY -</td>
<td>Black</td>
</tr>
</tbody>
</table>

3.8.5 CAN BUS COMMUNICATIONS

The AC Drive employs an isolated CAN bus interface. As an example Figure 12 illustrates the wiring configuration for AC Drive on a CAN network without one or more no isolated CAN nodes. The CAN Bus must be wired in a “Daisy chain” arrangement as shown in Figure 12. Twisted pair wiring is required for the CAN_H and CAN_L signals. Both physical ends of the CAN Bus must be terminated with 120 ohm resistances. A service device connector in a safe, convenient location should be included in the wiring configuration. Additionally, CAN Bus wiring should be physically separated from conductors carrying high currents.

The CAN bus is often opto-isolated to get sufficient noise margins in units that are switching high currents (such as AC DRIVE). In these units, CAN GND is a reference point for the CAN communication (CAN H and CAN L). CAN GND should be connected to B- at one point, and preferably one point only. If all units on the CAN bus are isolated, CAN GND should be externally connected to B- (see Figure 12).
3.9 **I/O CONNECTIONS**

In applications where the AC Drive is configured to accept control signals from the vehicle’s speed/potentiometers and digital signals for direction etc. The CANbus can be used for connection of a service tool. With the service tool error log, runtime registers etc can be read. The tool can also download new SW.

![Connection Diagram for digital and analog I/O](image)

**Figure 13: Connection Diagram for digital and analog I/O**
3.9.1 Connection Diagram

AD 4805
Connector K1
23 p AMP seal

Switch KEY ON
Fuse 1 A

Charge Mode
K1 (Relais)

Drive Mode

B+

Speed Poti (5 or 10 kOhm)

Motorfeedback (sin/cos)

Motor TEMP KTY84 +

ENPO (Enable Power Output)

Diode 1N4007

120 Ohm

Fw/Reverse

3.9.2 Motor Connector (Analogue Hallsensor and KTY 84 Series)

- cosinus Output - brown
- sinus Output - rose
- KTY + white (to ACD)
- KTY + red (from Motor)
- n.c.
- Vcc (+5 V) - green
- GND - yellow
- KTY – (GND) - black (from Motor)
3.10 **MAIN CONTACTOR**

The main contactor functions as both a power distribution component and key component of the AC Drive safety and protective interlocks circuit (see Figure 3). The main contactor is energized when the AC Drives and the motors they control are ready and available to execute motion.

When, as the result of some error/fault condition motion is not permitted, the main contactor is deenergized. During vehicle power-up the main contactor allows direct application of battery power to the AC Drive only after filter capacitors in the AC Drive have charged.

The following power output verses DC Input current relationship may be used when sizing a main contactor and associated cabling:

\[
I_{DC_{\text{IN}}} (DC \text{InputCurrent}) = \frac{\text{poweroutput}[kVA]}{VBATT[V \text{DC}]}
\]

**Note that removing power in this manner does not stop motor or produce any braking action. With driving power removed, Motors and components they drive simply coast to a stop. A mechanical brake must be used to stop the vehicle motion in this situation.**

3.11 **EMERGENCY STOP SWITCH**

A manually operated Emergency Stop switch is usually included in the main contactor energization circuit (see Figure 3). When activated, the Emergency Stop switch de energizes the main contactor, removing battery power from the power conversion section of the AC Drives.
4 START UP & COMMISSIONING

The AC Drive is a software configurable device. In a CAN (Controller Area Network) based system, all aspects of AC Drive setup and operation are managed by a truck controller. This section presents a general procedure for the startup and verification of an AC Drive following installation in an operational system (vehicle).

Built-in diagnostic functions monitor battery voltage, heatsink temperature and motor temperature along with a number of additional error conditions. Warning and error conditions are logged in Warning and Error status words, which are accessible to the truck controller. The Troubleshooting guide provides procedures for pinpointing and eliminating the causes of warning and error conditions.

4.1 CHECKS PRIOR TO INITIAL POWER UP

Perform the following before applying power to an AC Drive for the first time:

1. Verify that the proper AC DRIVE item number for the application has been installed. Verify that the vehicle battery voltage matches the AC DRIVE’s Nominal DC Supply Voltage rating listed on the product identification label affixed to the AC Drive (see Figure 2).
2. Verify that all power and signal wiring to the AC DRIVE is correct.
3. Verify that connections to battery and motor terminals are tight.
4. Verify that the control I/O connector is fully mated and latched into position with the mating connector (K1) on the AC DRIVE.
5. Verify that the AC DRIVE is correctly fused for the application. Refer to the vehicle manufacturer’s maintenance documentation for the correct fuse size.
6. On a traction application, block up or otherwise disable drives wheels to prevent the possibility of unexpected vehicle motion or motion in the wrong direction during initial checkout. On a lift application, open the valve to prevent the possibility of excess pressure build-up (in the event of a pressure relief valve malfunction).

4.2 VERIFYING AC DRIVE READINESS FOR OPERATION

The following procedure is to verify that an AC Drive is functional and able to communicate over the CAN Bus.

1. Apply battery power to the key start input. This applies logic power to the AC DRIVE.
2. Verify that the green LED indicator on each AC DRIVE is in the steady on condition. If the indicator is flashing or off, it indicates an error/warning or other fault condition exists within the AC DRIVE.
3. Consult the Troubleshooting guide of this manual for possible causes and corrective actions.
4.3 Configuring the AC Drive for the Application

As shipped from us in the beginning of a truck development project, the AC Drive is pre configured with a set of default parameters appropriate for the drive model and motor designated to be controlled by the AC Drive. These default parameters enable the Drive and it’s motor to operate at fraction of their potential during initial start-up and checkout. A necessary step in the AC Drive start-up procedure is to update those AC Drive parameters adjustable by the user to the values established for the application. The user-adjustable parameters are specified in the Object dictionary.

The general procedure for obtaining the correct configuration in the final product requires normally that the established parameter values are used as default values in the from us shipped AC Drives. The exceptions are the following:

- The truck controller (or other device) downloads parameter values that are depending on the truck configuration chosen in for example production and/or in the field (for example performance modes). In order to retain a configuration, the parameters have to be stored in the AC Drive's non-volatile memory (EEPROM). Thereafter the configuration is not changed until another configuration is downloaded and stored in the same manner. Consult the vehicle manufacturer’s maintenance information for specific instructions for performing this task.

- When parameters are continuously updated via the real time data exchange from the truck controller to the AC Drive.

The truck controller, by – for example – reading the checksum for all parameters stored in the AC Drive's EEPROM, can detect the situation where a drive’s configuration (set of parameter values) is not correct for the application and normally prohibits vehicle operation until the AC Drive has been correctly configured.

**WARNING**

- All AC Drive parameter values established have to be verified and validated prior to that the parameter values are used in the field by the end user

- This must be done in order to establish that all safety critical functions in the vehicle, for example braking are working properly.

- The complete range of parameters values that are updated by the vehicle controller (or any other device) has also to be verified and validated prior to that parameter values are used in the field by the end user

- During the process when the parameter values are established it is of major importance to take proper safety precautions when testing since wrong parameter values may jeopardize the operation of the vehicle safety critical functions.
4.4 **OPERATIONAL CHECKS IN VEHICLE**

<table>
<thead>
<tr>
<th>WARNING</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ For lift applications, make sure the pump rotates in the proper direction. Rotating in the wrong direction may damage the pump.</td>
</tr>
<tr>
<td>▪ Make sure that the motor and battery cables are connected correctly. Incorrect motor or battery connections may destroy the AC Drive</td>
</tr>
</tbody>
</table>

1. With the main contactor open (not enabled), apply battery power to the AC Drive’s B+ (or +) terminal through the inrush current limiting resistance.

2. Before enabling the main contactor, verify that the AC Drive’s filter capacitors have charged. The filter capacitors are fully charged when the voltage measured between the AC Drive’s + and B- terminals has reached battery voltage level.

3. Enable the main contactor.

4. Verify that the AC Drive and it’s associated motor start, stop and run properly at slow speed and at full operational speed. Refer to Motor speed sensor.
5 MAINTENANCE

This section presents a list of periodic preventive maintenance items and procedures for replacing an AC Drive.

The AC Drive contains no user adjustable or user replaceable components beneath its protective cover. Do not remove the cover. Do not clean the AC Drive using high-pressure water.

CAUTION

- If drive was recently in operation, heatsink may be too hot to touch. If necessary, allow the heatsink to cool before attempting to remove drive.
- Before removing or installing an AC Drive, disconnect battery power from B+, + and KEY START inputs.
- Wait 5 minutes for internal filter capacitors to self-discharge, or apply a 100 ohm resistance between + and B- terminals for 15 seconds to discharge the filter capacitors.
- To prevent personnel injury and protect the AC Drive from possible damage due to voltage transients, the AC Drive’s internal filter capacitors must be discharged as described in “Drive Removal”. Do not short the + to B- terminal.

5.1 PERIODIC PREVENTIVE MAINTENANCE

The recommended periodic preventive maintenance procedures for the AC Drive are minimal. We recommend the following items be performed every six months (or more frequently if necessary):

1. Remove all power from the drive. Apply a 100 ohm resistance between + and B- terminals for 15 seconds to discharge the filter capacitors.
2. Remove accumulated dust and debris from the AC Drive. If air is used, use only air with low pressure.
3. Retighten the bolts on the motor and battery terminal posts. (Torque requirement, See Motor and battery connections)
4. Retighten the bolts on the AC Drive (Torque requirement, See Mounting AC Drive)
5. **DRIVE REMOVAL**

1. Remove all power from AC Drive’s B+, + and key start inputs.
2. Wait 5 minutes for internal filter capacitors to self-discharge, or apply a 100 ohm resistance between + and B- terminals for 15 seconds to discharge the filter capacitors.
3. Remove bolts from battery and motor terminals and remove wires. Label the wires prior to removal if not already labeled.
4. Depress locking latch on connector housing and remove mating connector from K1.
5. Remove bolts securing drive to the vehicle. Then remove drive from the vehicle.

5.3 **DRIVE INSTALLATION**

1. Verify that battery power to the B+, + and key start inputs has been removed.
2. Clean the mounting surface before applying thermal grease on the unit before mounting. See Tools and equipment required.
3. Mounting AC Drive
4. Install motor wires, battery wires and tighten the bolts. (Torque requirement, See Motor and battery connections)
5. Insert mating connector into K1.
6. Perform initial start-up per the procedure titled Start up & commissioning.
6 TROUBLESHOOTING GUIDE

6.1 GENERAL

This troubleshooting guide presents procedures for diagnosing and eliminating the causes of faults and error conditions affecting the AC Drive. The AC Drive is one component of a drive chain, which may include mechanical drive components, a motor, hydraulics, electrical controls, wiring and battery. AC Drive errors/faults may result from condition external to the AC Drive. This troubleshooting guide addresses causes internal as well as external to the AC Drive, which may produce fault or error conditions within the AC Drive.

6.2 DOCUMENTATION FOR OEMS

The troubleshooting charts in this section are generic in nature and designed to stand alone in order that OEMs may easily incorporate this information into their documentation for the vehicle. We can provide this troubleshooting information on electronic media in various formats for OEMs who wish to import it into their documentation.

6.2.1 ERRORS

The AC Drive continuously monitors its internal operation as well as its interaction with the motor and truck controller. Errors are serious problems, which prohibit continued operation of the AC Drive.

When an error is detected
- The AC Drive operating software immediately stops motion then shuts down the drive’s power output to the motor.
- The error bit in the Status Word is set.
- The error bit GENERIC in the Error Register is set.
- The appropriate error bit in the Extended Error register is set.
- Sends out the high priority EMCY message with the Error Code.
- The Error Code and the time are saved to the Error Log.
- The Time is saved to the Operation Times.
- The LED indicator starts to flash fast (10Hz).

6.2.2 WARNINGS

Less serious problems, which permit continued AC Drive operation, often at reduced capacity, produce warnings. The AC Drive’s internal warning status is updated to reflect the code(s) for existing warning conditions. Operating with active warning conditions does affect the AC Drive status LED indicator, which changes from steady on to slow (1Hz) flashing. When the root cause of a warning is removed, the AC Drive automatically removes any reduced capacity restriction related to the warning condition.
When a warning is detected:

- The warning bit in the Status Word is set.
- The appropriate warning bit in the Extended Error register is set.
- The LED indicator starts to flash slowly (1Hz).

6.2.3 STATUS INDICATOR

The status indicator, shown in Figure 14, provides a visual identification of the AC Drives operating status.

<table>
<thead>
<tr>
<th>STATUS</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steady green light</td>
<td>The controller is OK</td>
</tr>
<tr>
<td>Fast flashing light. (10Hz)</td>
<td>An error is reported to the controller. When an error occurs, the AC Drive immediately stops motion then shuts down the drive’s power output to the motor.</td>
</tr>
<tr>
<td>Slow flashing light. (1Hz)</td>
<td>A warning is active</td>
</tr>
</tbody>
</table>
6.3 Using the Troubleshooting Guide

This troubleshooting guide is organized by visual symptoms and error/warning codes produced by the AC Drive. Error/warning codes are usually displayed or available on an operator display under supervision of the truck controller. For each visual symptom and error/warning code there is a troubleshooting chart that lists possible causes and corrective actions.

Each troubleshooting chart presents:
- Possible causes and relevant conditions (in oval blocks)
- With connections to corrective actions (in rectangular blocks).
- Supplemental comments and explanations are enclosed in oval shaped blocks constructed with dashed lines.
- When using a troubleshooting chart, one should first investigate those possible causes, which seem most likely considering the recent history of the vehicle.

Locate the observed symptom(s) in Table 6, error code in Table 7 and warning code in Table 8, and then refer to the troubleshooting chart on the referenced page. After performing a corrective action, restart the AC Drive and verify that the error/warning does not reoccur. If the error/warning does reoccur, proceed to the next corrective action on the troubleshooting chart.

### Table 6: Symptom verses Troubleshooting Cart

<table>
<thead>
<tr>
<th>Symptom Code</th>
<th>See page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main contactor doesn’t close within 10 sec. after switching on the KEY SWITCH</td>
<td>NA</td>
</tr>
<tr>
<td>Fuse to Power Stage is blown</td>
<td>NA</td>
</tr>
<tr>
<td>AC Drive Status indicator is flashing or off</td>
<td>NA</td>
</tr>
<tr>
<td>Motor runs only at low speed, with a ticking sound</td>
<td>NA</td>
</tr>
</tbody>
</table>

### Table 7: Emergency Error Code

<table>
<thead>
<tr>
<th>Emergency Error Code</th>
<th>Extended Error bit field code index 3010h,2</th>
<th>ERROR</th>
<th>See Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x2310</td>
<td>0x2000</td>
<td>AC Current – Over current</td>
<td>NA</td>
</tr>
<tr>
<td>0x2340</td>
<td>0x0001</td>
<td>AC Current – Short circuit</td>
<td>NA</td>
</tr>
<tr>
<td>0x3120</td>
<td>0x0010</td>
<td>No Charging DC Bus</td>
<td>NA</td>
</tr>
<tr>
<td>0x3211</td>
<td>0x0004</td>
<td>DC Bus high – software detected</td>
<td>NA</td>
</tr>
<tr>
<td>0x3212</td>
<td>0x0008</td>
<td>DC Bus high – hardware detected</td>
<td>NA</td>
</tr>
<tr>
<td>0x3221</td>
<td>0x0002</td>
<td>DC Bus low</td>
<td>NA</td>
</tr>
<tr>
<td>0x4210</td>
<td>0x0040 / 0x0080</td>
<td>Heatsink Over temperature</td>
<td>NA</td>
</tr>
<tr>
<td>0x5111</td>
<td>0x0400</td>
<td>15 V Supply low voltage</td>
<td>NA</td>
</tr>
<tr>
<td>0x5113</td>
<td>0x0800</td>
<td>15 V Supply low or high voltage</td>
<td>NA</td>
</tr>
<tr>
<td>0x5210</td>
<td>0x0200</td>
<td>Current sensor offset calibration error</td>
<td>NA</td>
</tr>
</tbody>
</table>

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Table 7: Error verses Troubleshooting Chart

<table>
<thead>
<tr>
<th>Code Index 3010h,2</th>
<th>Warning</th>
<th>See page</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x5410 0x1000</td>
<td>Open Drain Output Current High</td>
<td>NA</td>
</tr>
<tr>
<td>0x8100 0x0100</td>
<td>CAN Time Out</td>
<td>NA</td>
</tr>
</tbody>
</table>

Table 8: Warning verses Troubleshooting Chart

<table>
<thead>
<tr>
<th>Extended Warnings Bit field code Index 3010h, 1</th>
<th>Warning</th>
<th>See page</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0001</td>
<td>Low Voltage</td>
<td>NA</td>
</tr>
<tr>
<td>0x0002</td>
<td>High Voltage</td>
<td>NA</td>
</tr>
<tr>
<td>0x0004</td>
<td>DC Bus calibration</td>
<td>NA</td>
</tr>
<tr>
<td>0x0008</td>
<td>Motor temperature low, &lt; - 50°C</td>
<td>NA</td>
</tr>
<tr>
<td>0x0010</td>
<td>Motor temperature high; &gt; 145°C</td>
<td>NA</td>
</tr>
<tr>
<td>0x0020</td>
<td>Motor temperature sensor not connected or short circuit</td>
<td>NA</td>
</tr>
<tr>
<td>0x0040</td>
<td>Heatsink temperature 1 low &lt; - 20°C</td>
<td>NA</td>
</tr>
<tr>
<td>0x0080</td>
<td>Heatsink temperature 1 high &gt; 85°C</td>
<td>NA</td>
</tr>
<tr>
<td>0x0100</td>
<td>Heatsink temperature sensor 1 not connected or short circuit</td>
<td>NA</td>
</tr>
<tr>
<td>0x0200</td>
<td>Heatsink temperature 2 low &lt; - 20°C</td>
<td>NA</td>
</tr>
<tr>
<td>0x0400</td>
<td>Heatsink temperature 2 high &gt; 85°C</td>
<td>NA</td>
</tr>
<tr>
<td>0x0800</td>
<td>Heatsink temperature sensor 2 not connected or short circuit</td>
<td>NA</td>
</tr>
<tr>
<td>0x1000</td>
<td>Default parameters</td>
<td>NA</td>
</tr>
<tr>
<td>0x2000</td>
<td>Power reduction due to temperature (motor or heatsink)</td>
<td>NA</td>
</tr>
<tr>
<td>0x4000</td>
<td>Speed feedback sensor not connected or short circuit</td>
<td>NA</td>
</tr>
<tr>
<td>0x8000</td>
<td>Current Measurement Calibration</td>
<td>NA</td>
</tr>
<tr>
<td>0x40000</td>
<td>Open Drain Output High Warning</td>
<td>NA</td>
</tr>
<tr>
<td>0x80000</td>
<td>Open Drain Output Current High Error</td>
<td>NA</td>
</tr>
</tbody>
</table>
7 AC DRIVE SPECIFICATIONS

7.1 GENERAL

Motor Types: 3-phase PM synchronous motor
No. of Quadrantes 1, 2, 4 quadrant control
Braking: Regenerative
Modulation: PMW (Pulse Width Modulation)
Switching Frequency 8 kHz
Control mode Speed or Torque control

7.2 CURRENT AND POWER OUTPUT RATINGS

<table>
<thead>
<tr>
<th>AC Drive model</th>
<th>Nominal DC supply voltage Udc (see note 3)</th>
<th>Driving current (2 min. rating) (see note 1)</th>
<th>Power output (2 min. rating) (see note 2)</th>
<th>Power output (1 hour rating) (see note 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4805</td>
<td>24-48 V DC</td>
<td>200 A rms</td>
<td>75 A rms</td>
<td>9.3 kVA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.8 kVA</td>
</tr>
</tbody>
</table>

Switching frequency 8 kHz

Note 1: Driving current (one hour rating) and power output (one our rating) based cooling requirement for both heatsink version and air temperature of 40 °C, see Operating enviroment.

Note 2: Driving current (2 min rating) and power output (2 min rating) based on initial heatsink temperature of 25 °C, air temperature of 25 °C, and cooling requirement for both heatsink version, see Operating enviroment.

Note 3: Uac output voltage to the motor is approx \((Udc-3V)/\sqrt{2}\)

7.3 DC SUPPLY VOLTAGE REQUIREMENT

<table>
<thead>
<tr>
<th>AC Drive model</th>
<th>Nominal DC Supply Voltage VDC</th>
<th>Operating range VDC</th>
<th>Insantaneous minimum (&lt; 100 ms) VDC</th>
<th>Insantaneous maximum (&lt; 10 s) VDC</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACD 48xx</td>
<td>48</td>
<td>18-63</td>
<td>24</td>
<td>58</td>
</tr>
</tbody>
</table>
7.4 **ISOLATION**

B-Terminal to Headsink: According to EN 1175-1 and UL 583
500 – 1200 V AC: 1 Min.

7.5 **CAN Communications Interface**

CAN Protocol: CANopen
Physical Interface: ISO 11898
Bitrate: 125, 250 and 500 kBit/s

7.6 **SAFTY System**

**GENERAL**
- When error is detected, controller disable power output within 100 ms
- CAN communication watchdog time out 50 ms
- Errors are reported via the CAN link
- When controller is okay, LED indicator on the controller is steady green
- When error condition(s) exist, LED is flashing fast (10 Hz)
- When warning condition(s) exist, LED is flashing slow (1 Hz)

**OVERCURRENT**
Power Conversion section disabled on over current condition

**UNTERVOLTAGE**
Power Conversion section disabled if + (battery voltage) input < lower limit DC supply voltage operating range for unit

**OVERVOLTAGE**
Power Conversion section disabled if + (battery voltage) input > upper limit DC supply voltage operating range for unit

**THERMAL PROTECTION**
Linear current rollback beginning at 85 °C, down to 0A at 125°C on heatsink. Below ~20°C, peak current reduced to 60% of two minute rating

**THERMAL PROTECTION MOTOR**
Linear current rollback beginning at 145°C, down to 0A at 165°C in motor

7.7 **OPERATING ENVIRONMENT**

Operating Temperature: -40°C to + 55°C
Storage Temperature: -40°C to +70°C, ambient humidity of 95%
Humidity: 100% condensing according to IEC 68-2-30, Db
7.8 **EMC**

Electromagnetic Compatibility According to European standard EN 12895; Industrial Trucks (radiated immunity, emission, ESD)

Electrical FAST/Transient / Burst EN 61000-4-4 level 2

7.9 **SAFETY AND TESTING STANDARDS COMPLIANCE**

Safety, Industrial Trucks EN 1175.-1

Basic Environment Testing Procedure IEC 68-2-30 Damp Heat Cycle

Protection Class IP 54 Test IEC 60529 (with mating connector K1 installed)

7.10 **MECHANICAL TESTS**

VIBRATION IEC 68-2-64, Test FH, level 2

BUMP IEC 68-2-29, Test EB

SHOCK IEC 68-2-27, Test EA

7.11 **WEIGHT**

<table>
<thead>
<tr>
<th>AC Drive model</th>
<th>Weight kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACD 4805</td>
<td>1.6</td>
</tr>
</tbody>
</table>

7.12 **DIMENSIONS**

Figure 15 shows dimensions for AC Drive model 02 and 05 and drilling pattern for the flat heatsink versions and surface roughness and surface flatness demands for the flat heatsink versions. (Dimensions are in mm).

ACDxx02  X = 8

ACDxx05  X = 12.5

Apply heatconductive grease