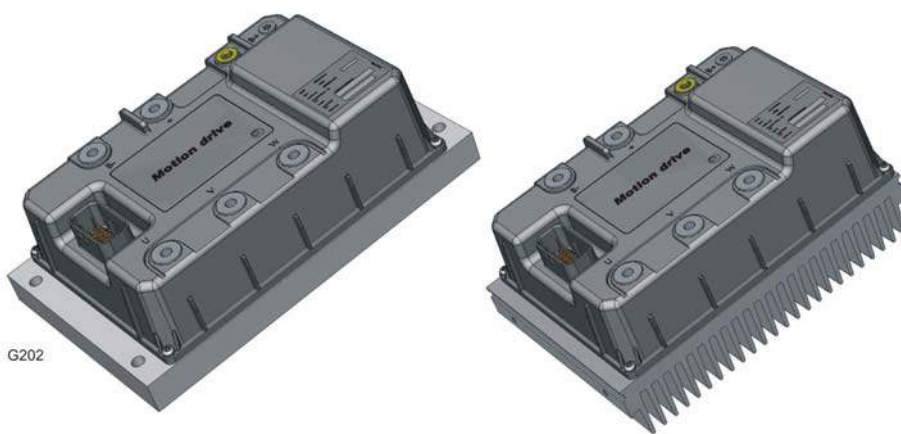


www.danahermotion.se

AC SuperDrive

The AC motor controller
Generation 5



User's Guide 1.0

Item No. 89Y05120A

26.04.2005

Solution by


Version History		
Revision	Edition date	Reason for revision

Trademark information here

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1 INTRODUCTION

1.1 ABOUT AC SUPERDRIVE DOCUMENTATION

1.1.1 THIS VERSION

This version replaces all previous versions of this document. Danaher Motion Stockholm AB has made every effort to insure 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 COPYRIGHT

This manual is copyrighted 2005 by Danaher Motion Stockholm AB. All rights reserved. This manual may not be copied in whole or in part, nor transferred to any other media or language, without the express written permission of Danaher Motion Stockholm AB.

1.1.3 SCOPE

This manual presents instructions, guidelines, diagram and other information relevant for installation and maintaining the AC SuperDrive in an electrically powered vehicle utilizing the CAN Bus and CANopen protocol for communications and control.

1.1.4 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.

	<p>WARNING</p> <ul style="list-style-type: none"> ◆ A Warning informs the user of a hazard or potential hazard that could result in serious or fatal injury if the precautions or instructions given in the warning notice are not observed.
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	<p>CAUTION</p> <ul style="list-style-type: none"> ◆ 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.
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	<p>An Information Box contains supplemental information or references to supplemental information on a topic.</p>
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	<p>Stop Box highlights important conceptual or procedural details that must be understood and applied in order to successfully use the product.</p>
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1.1.4.1 PRODUCT RANGE

This manual presents important information about the AC SuperDrive Product Generation (5) five.

1.1.5 RELATED DOCUMENTS


Object Dictionary (document number 89Y05110A). The Object Dictionary provides important information about CANopen communication with the AC SuperDrive.

1.2 ABOUT THE AC SUPERDRIVE

1.2.1 PERSONAL SAFETY

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

	<p>WARNING</p> <ul style="list-style-type: none">◆ The high power levels and high torque available from a motor, AC SuperDrive combination can cause severe or fatal injury.
-----------------------------------------------------------------------------------	---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

	<p>CAUTION</p> <ul style="list-style-type: none">◆ The AC SuperDrive 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 SuperDrive 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 SuperDrive.
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1.2.2 OEM'S RESPONSIBILITY

The Danaher Motion AC SuperDrive 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 SuperDrives 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 in which a non-professional has done installation, service or repair and when the system is used for other than its intended purpose.

1.2.3 TECHNICAL SUPPORT

For additional information on any topic covered in this document, or for additional information or application assistance on any Danaher Motion Stockholm AB product, contact a Danaher Motion Stockholm AB Application Center listed in the front of this manual.

1.2.4 REPAIR

Repair and testing of the APS is available at Danaher Motion Stockholm AB.

The address is listed on page 99.

When returning defective unit in North America, contact Danaher Motion Stockholm AB in Sewickley and obtain a RMA (Returned Materials Authorization) number prior to returning the defective unit. Indicate the RMA number on the shipping container and paper work that accompanies the returned unit.

1.2.5 PRODUCT WARRANTY

Refer to the sales agreement or contract under which the AC SuperDrive was purchased for a complete statement of the product warranty.

1.3 PRODUCT IDENTIFICATION

1.3.1 CONFIGURATIONS

The AC SuperDrive is manufactured in the following two configurations:

- Convection cooled models (see [Figure 1](#)) employing a heat sink with cooling fins that transfer heat to the surrounding air by convection.
- Conduction cooled models (see [Figure 1](#)) with a flat heat sink and mounting surface that transfers heat into the surrounding vehicle structure by conduction.

1.3.2 AC SUPERDRIVE IDENTIFICATION LABEL

A label containing pertinent product identification information is affixed to the AC SuperDrive cover next to the B+ terminal post. The product label fields relevant to product identification are described below. For AC SuperDrive expressions, see [Table 1](#). See [Figure 1](#) for placement and [Figure 2](#) for a label appearance.

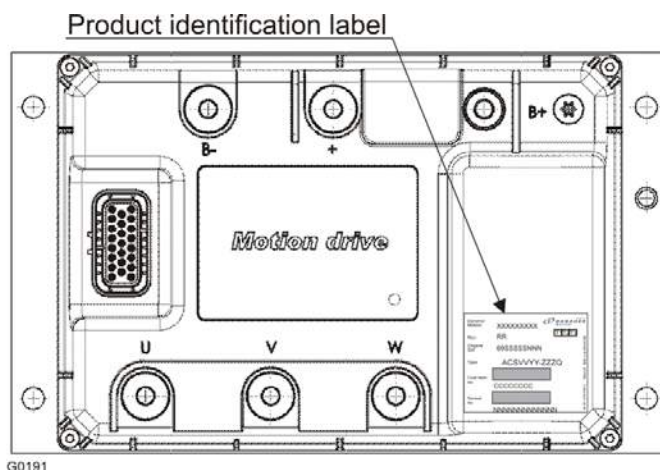


Figure 1. AC Superdrive with fins and flat Mounting Surface.



Figure 2. AC SuperDrive Product Identification Label.

Field	Description
Danaher Motion	Unique part number assigned to AC SuperDrives with a specific hardware and software configuration. AC SuperDrives with the same part number and revision are identical.
Rev.	Indicates the revision level of the item.
Type	<p>AC SuperDrive ACSVVYY-ZZZQ00 00=Option F = Fins C = Cold plate</p> <p>Nominal DC Supply Voltage 24 = 24 VDC 36 = 36 VDC 48 = 48 VDC 80 = 80 VDC</p> <p>Peak current A (2min) Unit Size (L) 10 = 165 mm length 15 = 233.6 mm length 20 = 302.2 mm length 25 = 370.8 mm length</p> <p>* Contact Danaher Motion Stockholm AB for further information.</p>
Serie No.	Production lot number (assigned by the factory). The production lot number together with the sequence number yield a unique serial number for each AC SuperDrive.
Serie No.	Serial number within a production lot.
Manufacture date	Year, month and day of manufacture.

Table 1. AC SuperDrive Product expressions.

1.4 STANDARD FEATURES AND CAPABILITIES

The AC SuperDrive 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 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).
- Recycles dynamic braking energy down to zero speed.
- Fully protected against undervoltage, overvoltage, overcurrent and reverse polarity and overtemperature 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 truck control system.
- Total software configurability eliminates all operator adjustments and assures absolutely reproducible performance of identically configured AC SuperDrives.
- All heat generating components mounted on a massive heatsink whose temperature is monitored.
- Error/fault monitoring software implements necessary measures to prevent unsafe operation of vehicle and motor/drive when 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.

1.5 AVAILABLE OPTIONS

The following are available options for the AC SuperDrive:

- BDI. (Battery Discharge Indicator)
- Programmable Best Performance Curve, see page [53](#).

2 OVERVIEW

In a typical CAN based system (see [Figure 3](#)), one AC SuperDrive directs the motion of a lift motor powering a hydraulic pump while a second AC SuperDrive directs the motion of a traction motor coupled to a drive wheel. AC SuperDrives convert DC power from the truck's battery to three phase AC power at the frequencies and currents necessary to drive their respective induction motors as commanded.

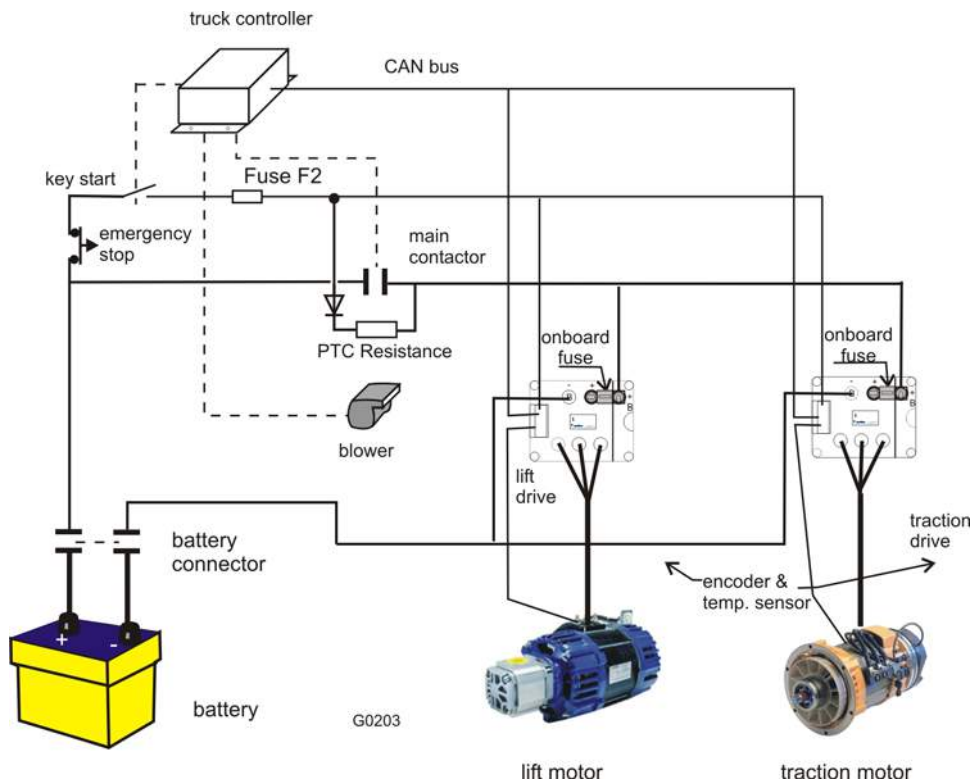


Figure 3. The Truck Drive System

The main contactor, under control of the truck controller, supplies battery power to the power conversion section of the drives and removes battery power under certain error and fault conditions. An onboard fuse protects each drive against short circuit faults in the power conversion section.

A PTC (Positive Temperature Coefficient) resistance limits inrush current to a bank of filter capacitors when power is first turned on via the disconnect switch.

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

Each motor provides feedback of its speed, direction and temperature to the AC SuperDrive for control and monitoring purposes. A speed encoder integrated into each 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 truck controller, based on input from operator controls and other criteria, transmits speed, braking and other commands to the AC SuperDrives 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 SuperDrive power stage.

2.1 PRINCIPLES OF OPERATION

2.1.1 BLOCK DIAGRAM

Figure 4 shows a functional block diagram of the AC SuperDrive 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.

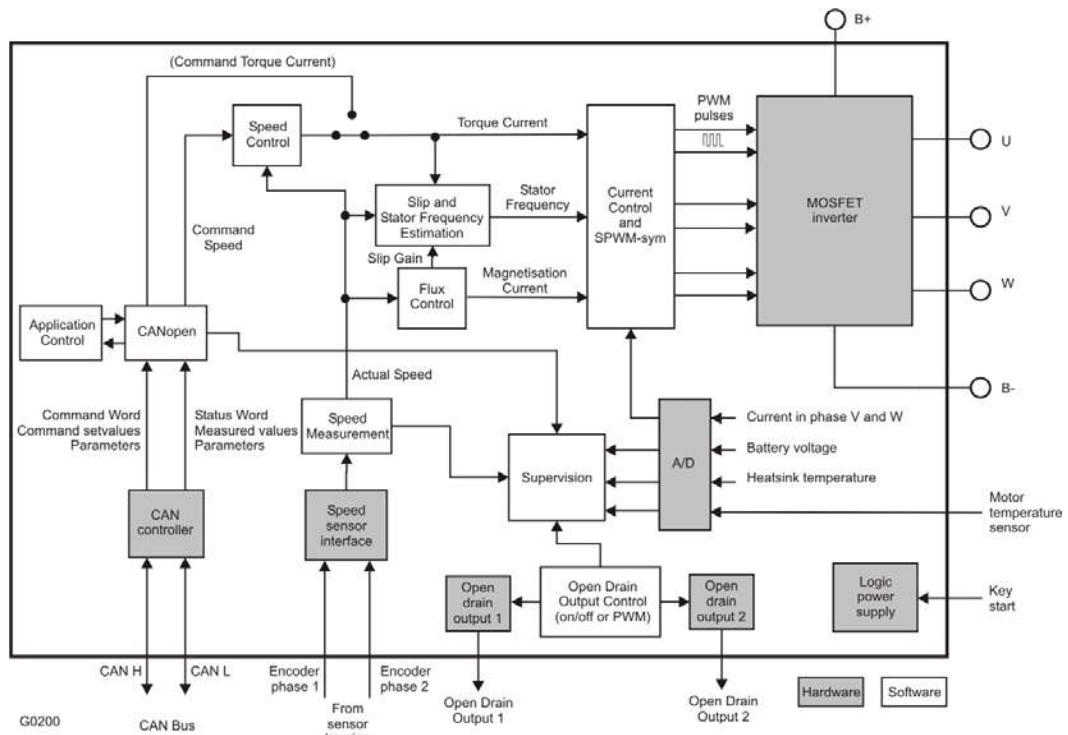


Figure 4. AC SuperDrive Block Diagram

2.1.2 CAN INTERFACE

The CAN Interface manages communications between the AC SuperDrive 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 speed encoder. It includes provisions for limiting torque both in amplitude and derivate. 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 FLUX CONTROL

The motor flux is controlled within the Flux Control. The Magnetization Current, which produces the motor flux, and the Slip Gain, which is reciprocally proportional to the Magnetization Current, is the outputs from the Flux Control. Since the motor flux depends on the motor speed, the measured motor speed is used to determine the optimal magnetization flux level.

2.1.5 SLIP AND STATOR FREQUENCY ESTIMATION

The Slip Speed and the Stator Frequency is estimated in the Slip and Stator Frequency Estimation. The Slip Speed is computed from the Slip Gain and the Torque Current. The Stator Frequency that is integrated in the Current Control to get the position of the dq-plane is computed as the sum of the Actual Speed (electrical) and the Slip Speed.

2.1.6 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 symmetrisation). The output from the SPWM-sym block is the MOSFET gate pulses.

2.1.7 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, a SuperDrive 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.

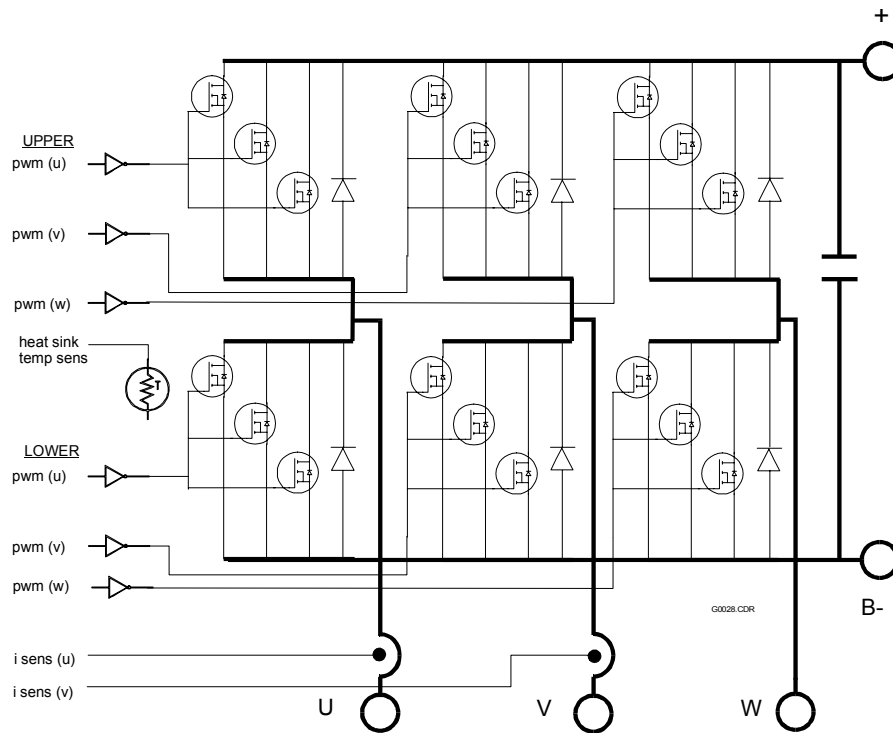


Figure 5. Power Conversion Section.

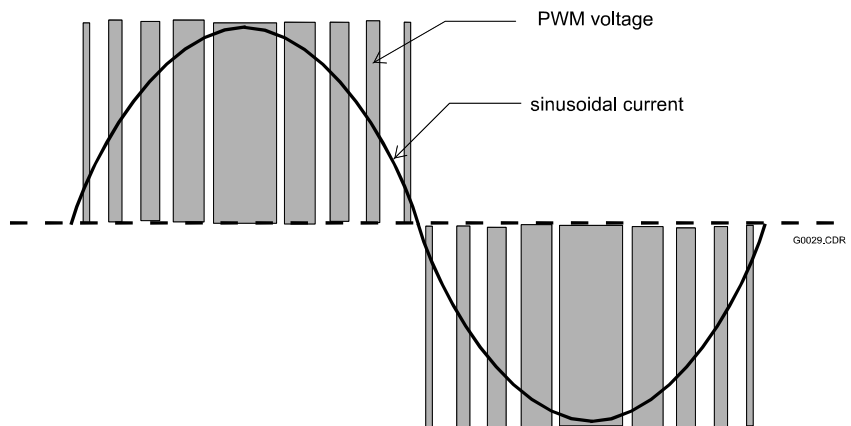


Figure 6. Pulse Width Modulation.

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 SuperDrive supplies a magnetizing current at the proper frequency for optimum regeneration performance. The generated power is dependent on the slip (which the AC SuperDrive 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.

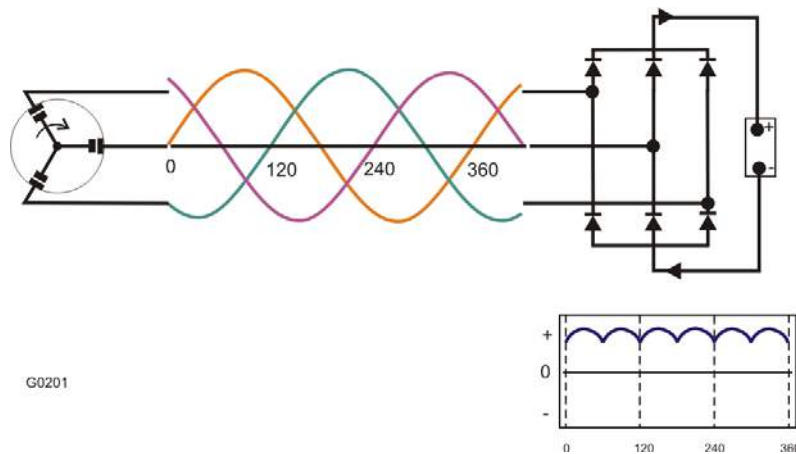


Figure 7. Current Flow During Regeneration.

2.1.8 SPEED SENSOR INTERFACE

The Speed Sensor Interface converts the quadrature pulse outputs from a speed encoder to digital speed and direction numbers for use by other drive and system functions.

2.1.9 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 SuperDrive 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 SuperDrive. Less serious problems that permit continued AC SuperDrive operation, often at reduced capacity, produce warnings.

For some items monitored, the AC SuperDrive 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.

i A complete Troubleshooting guide for the AC SuperDrive is presented at page 69.

2.2.2 ERRORS

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

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

2.2.3 WARNINGS

The AC SuperDrive'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 SuperDrive's status indicator, which remains in steady on condition. When the root cause of a warning is removed, the AC SuperDrive automatically removes any reduced capacity restriction related to the warning condition.

2.3 TRUCK CONTROLLER - AC SUPERDRIVE COMMUNICATIONS

2.3.1 GENERAL

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

OBJECT (MESSAGE) TYPE	PURPOSE
SERVICE DATA OBJECT (SDO)	Exchange of non-real time data and control.
PROCESS DATA OBJECT (PDO)	Exchange of real time data and control.
SYNCHRONISATION OBJECT (SYNC)	Broadcast periodically by the master to all slaves to synchronize network devices and processes with the master.
NETWORK MANAGEMENT(NMT)	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.
EMERGENCY (EMCY)	Transmitted by slaves to signal internal error conditions to the master.

The AC SuperDrives may be configured to utilize the periodic SYNC message from the truck controller (or other device on the CAN Bus) by which the SuperDrive confirms that the truck controller and CAN communications are functional. Upon reception of the SYNC object, the AC SuperDrive initiates the sending of a Transmit PDO containing a summary of its operating state. The AC SuperDrive 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 SuperDrive requires a periodic Receive PDO containing motion and related control variables. The AC SuperDrive can be configured to use one or two Transmit/Receive PDOs.

2.3.2 NODE IDENTIFICATION

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 SuperDrive on the CAN Bus determines its COB-ID via the wiring configuration on two contacts of the interface (connector K1) mating connector. Each AC SuperDrive on the Bus must have a unique ID.

3 INSTALLATION

3.1 INTRODUCTION

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

1 Mounting brackets, rails and attaching hardware are not supplied with the AC SuperDrive. These items must be ordered separately.

1 The bolt length is depending on thickness at the mounting brackets. The mounting brackets are not supplied by Danaher Motion Stockholm AB

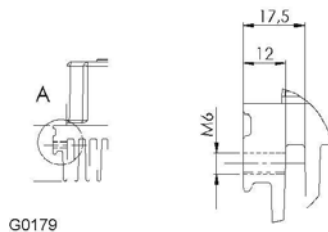


Figure 8. Calculate bolt length for mounting finned heatsink.

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

- AC SuperDrive's cover provides a measure of protection from liquids and particles dripping, splashing or spraying onto the unit; however, the AC SuperDrive 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 cooling fins on the bottom surface of the AC SuperDrive must remain relatively clean in order to effectively cool the unit. Avoid locating the AC SuperDrive where it may be subjected to high concentrations of dust, oil etc. which may accumulate on the cooling fins.
- The AC SuperDrive LED status indicator provides useful diagnostic information for troubleshooting of some vehicle problems. The troubleshooting process can be facilitated if this indicator is visible.
- Consideration should be given to accessibility of the on-board fuse.
- High power levels are available at each of the connection posts. Therefore they should be protected from accidental short circuits.

3.2 COOLING REQUIREMENTS

3.2.1 AC SUPERDRIVE WITH FINNED HEATSINK

A massive heatsink comprising the entire bottom surface of the AC SuperDrive transfers heat from the Power Conversion section components into the surrounding air. Drives operating at or near their continuous power output (1 hour rating) require forced air cooling to maintain heat sink temperature in the safe operating zone.

We recommend ambient temperature air at [Operating environment](#) at page 94 be directed over the heatsink fins to maintain heatsink temperature below 85 °C. Either an axial blower or two small muffin fans can provide the necessary airflow for two AC SuperDrives.

In typical applications, the truck controller monitors heatsink temperature and regulates either fan speed or on/off cycle to maintain heatsink temperature below 85 °C.

3.2.2 AC SUPERDRIVE WITH FLAT HEATSINK

A massive heatsink comprising the entire bottom surface of the AC SuperDrive 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 ACS size for dissipation of heat to maintain heat sink temperature in the safe operating zone. For thermal resistance see [Operating environment](#) at page 94.

3.3 CLEARANCES FOR ACCESS AND AIR CIRCULATION

For all AC SuperDrive models 50 mm clearances in front of and behind the AC SuperDrive are required for airflow. 50 mm clearance above the AC SuperDrive is required for installation/removal of interface connectors and wiring. Refer to [Figure 37](#) for dimensions for all AC SuperDrive.

3.3.1 AC SUPERDRIVE WITH FINNED HEATSINK

The AC SuperDrive is cooled by the airflow over the finned heatsink that forms its bottom surface. Clearance above and below the drive and between the heatsink and vehicle are required for air circulation. In some applications forced air-cooling is required (see [Operating environment](#)).

3.3.2 AC SUPERDRIVE WITH FLAT HEATSINK

The AC SuperDrive is cooled by the surface contact to the vehicle body. Observe demands to surface roughness and surface flatness where the AC SuperDrive is mounted to the vehicle body. Apply thermal grease (Amount, see page 21) at the AC SuperDrive before mounting for best cooling effect.

3.4 ORIENTATION

The AC SuperDrive is not to be orientated upsidedown; either horizontal or vertical mounting is acceptable, although a horizontally mounted unit tolerates higher levels of mechanical shock than a vertically mounted unit. When mounted vertically, the AC SuperDrive should be oriented with its cooling fins aligned vertically. Consideration should be given to accessibility of the on-board fuse and 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.

i

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

3.5 MOUNTING AC SUPERDRIVE WITH FINS HEATSINK

3.5.1 DIMENSIONS AND CLEARANCES

Figure 37 shows the drilling pattern and dimensions for the AC SuperDrive versions with fins at the heatsink.

3.5.2 TOOLS AND EQUIPMENT REQUIRED

The following tools and hardware are recommended for mounting an AC SuperDrive:

- Four (4) bolt M6S M6 x yy 8.8 fzb (yy mm see Figure 8) internal hex head bolts (pos 1).
- Four (4) washer BRB 6.4 HB 200 fzb (12 x 6.4 x 1.6) (pos 2).
- Two (2) mounting brackets, OEM supplied.
- 10 mm Box wrench.

3.5.3 PROCEDURE

The AC SuperDrive is secured to two (2) mounting brackets, (OEM supplied) using the following procedure:

1. Attach two (2) mounting brackets to vehicle (OEM supplied), torque according to used bolt dimension.
2. Install AC SuperDrive into mounting brackets (see Figure 9) and tighten attaching bolts to 10 Nm \pm 1Nm.

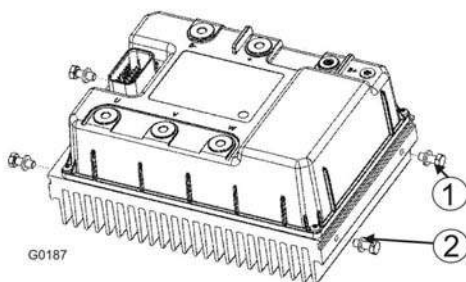


Figure 9. Installing AC SuperDrive with fins heatsink.

3.6 MOUNTING AC SUPERDRIVE WITH FLAT HEATSINK

3.6.1 DIMENSIONS AND CLEARANCES

Figure 38 shows the flat AC SuperDrive versions and the drilling pattern.

For additional details on surface roughness and surface flatness demands for AC SuperDrive flat heatsink version see Table 29. See also User's Manual (89R09090A) for installation instructions and torque.

3.6.2 TOOLS AND EQUIPMENT REQUIRED

The following tools and hardware are recommended for mounting an AC SuperDrive:

- Four (4) M6S M8 x 40 8.8 fzb (mm) bolts or equivalent (5/16 UNC) bolts, (pos 1).
- Four (4) washer BRB 8.8 HB 200 fzb, (16 x 8.4 x 1.5). Pos 2.
- 13 mm Box wrench.
- Thermal grease, type of grease is typically Electrolube HTC or Dow Corning 340.

Size	Amount (grams)
10	15
15	20
20	25
25	30

Apply the grease evenly over the whole surface.

3.6.3 PROCEDURE

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

1. Apply thermal grease (OEM supplied) evenly over the whole AC SuperDrive surface, mounted onto the vehicle.
2. Install AC SuperDrive to the vehicle body Figure 10 and tighten selected bolts (OEM supplied) slightly to the vehicle body.

Tighten the bolts from up left to right down to 23 Nm \pm 2Nm.

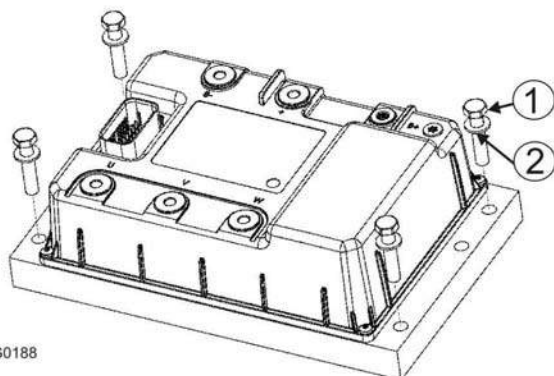


Figure 10. Installing flat heatsink AC SuperDriv

3.7 WIRING

This section provides schematic diagrams and related information for connecting AC SuperDrives into a vehicle in a CAN Bus based application. These circuit diagrams present basic - but functional - general purpose wiring configurations. AC SuperDrive users may choose to modify these generic-wiring configurations to fit their individual requirements or conventions.

3.7.1 MOTOR AND BATTERY CONNECTIONS

Figure 11 shows the basic power-wiring diagram for the AC SuperDrive and it's motor. This configuration utilizes an on-board fuse and main contactor under direct control of the truck controller. Table 2 provides a description of the six terminal post connections on the AC SuperDrive.

Terminal	Description
B+	Provides a tie point for connection of battery power to the on-board fuse (no connection to internal AC SuperDrive circuitry from this terminal).
+	Supplies fused battery power to the power stage that produces three-phase AC motor current.
B-	Battery return connection.
U, V, W	Phase connections for the three-phase induction motor.

Table 2. Motor and Battery Connections.

i Figure 11 is only a generic power schematic drawing. The actual wiring of a vehicle may differ from the configuration in Figure 11.

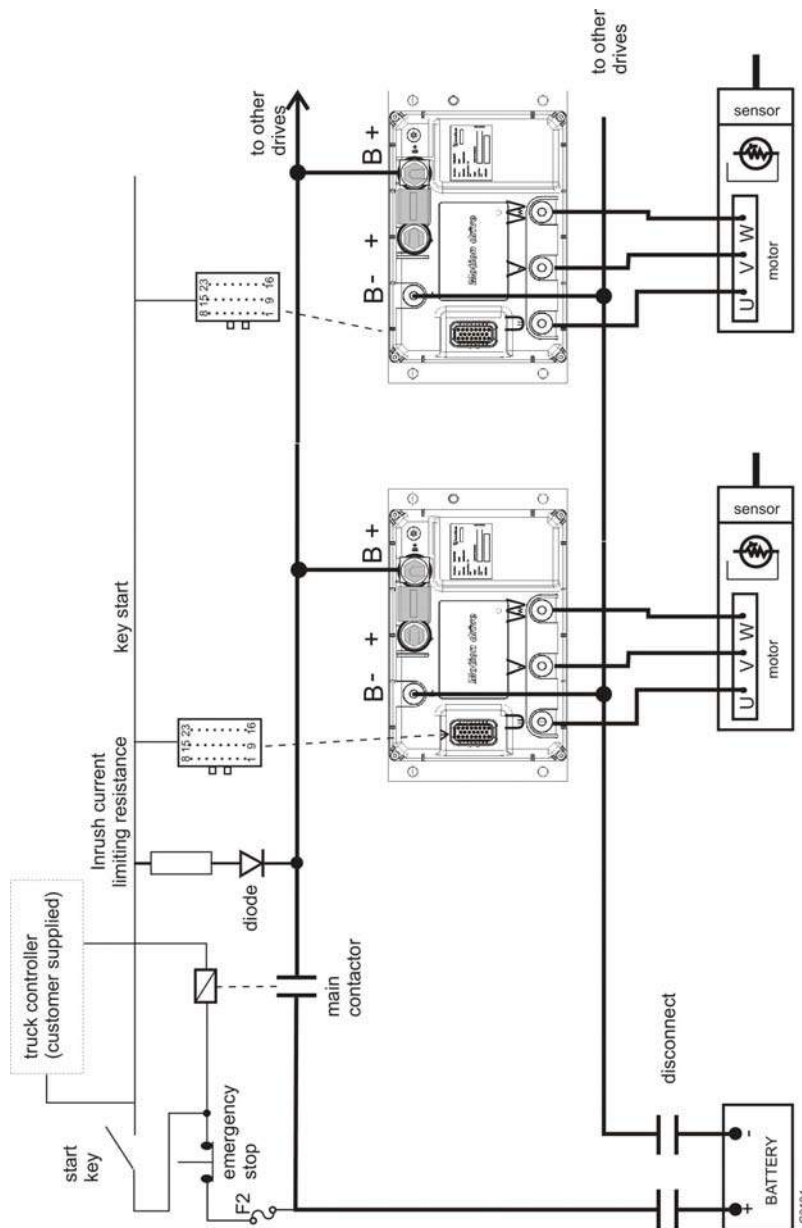


Figure 11. Motor and Battery Wiring Diagram with on-board fuse.

3.7.2 MAKING CONNECTIONS TO TERMINAL POSTS

Ring lugs for motor and battery connections must be properly rated to carry motor and battery currents; otherwise, overheating will occur. Crimp ring lugs onto the motor wires, then secure the lugs to terminal posts using bolts (M8 x 25 pos. no 1 and pos 7 in [Figure 14](#)) and lock washers and washers if necessary. (For L, see [Figure 12](#) and used bolt pos. no 7 in [Figure 14](#)).

If L is

- ≤ 5mm a shorter bolt (20 mm) must be used.
- 11-15 mm a longer bolt (30 mm) must be used.

- Thread depth $L_T = 20 +1, -0$ mm.

Figure 12. shows recommended connections to terminal posts (when bolt and washer/s are tightened). Use a torque wrench with 13 mm socket. Tighten the bolts to 15 ± 2 Nm.

3.7.3 EQUIPMENT REQUIRED

See Figure 14 for position number.

1. 2x Bolt M6S M8 x L 8.8fzb for on-board fuses/battery, (for L, see above and Figure 12).
2. 6x Lock washer (DIN 127B). Dim. 16x8.5x1.6mm or 5/16" ID.
3. 6x Washer BRB 8.8 HB 200fzb. Dim. 16x8.8x1.6mm or 5/16" ID.
4. Fuse. See page 26.
5. 3x 44R09025A Washer ordered from Danaher Motion Stockholm AB. (Tin plated copper washer).
6. 5x Ring lugs with 8.5 mm hole diameter for battery and motor connection.
7. 4x Bolt M6S M8 x L 8.8fzb for motor connection, (for L, see above and Figure 12).

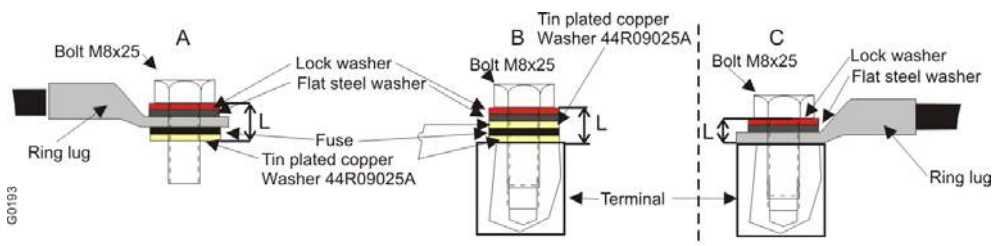


Figure 12. Recommended bolt length.

- A = Battery B+,
- B = Battery +,
- C = Motor connection and B-.

3.8 ON-BOARD FUSE SIZING AND SELECTION

1 An on board fuse is not supplied with the AC SuperDrive. This component must be ordered separately.

An on-board fuse installed between the B+ and + terminals on each AC SuperDrive protects the drive and power distribution circuit in the event of a short circuit fault in the power conversion section. Note that the on-board fuse is not intended to protect the AC SuperDrive or motor against overloads. Since the AC SuperDrive 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 SuperDrive and typically do not cause the on-board fuse to blow.

In lieu of an on-board fuse, a user may choose to locate this fuse off the drive (i.e. at a central fuse panel). In this configuration (see Table 2) battery power is connected to the AC SuperDrive + terminal.

The fuse should be sized based on the AC SuperDrive's power output (2 min. rating) listed on page 93. Compute DC input current as follows:

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

Select a fuse with rating and time delay characteristics which will carry I_{DC_IN} indefinitely, but blow within 2 - 3 seconds for $2 \times I_{DC_IN}$.

Figure 13 shows typical dimensions of the fuse for on-board mounting. Buss (ANN series), Pudenz and others manufacture fuses that satisfy the time delay and dimension requirements.

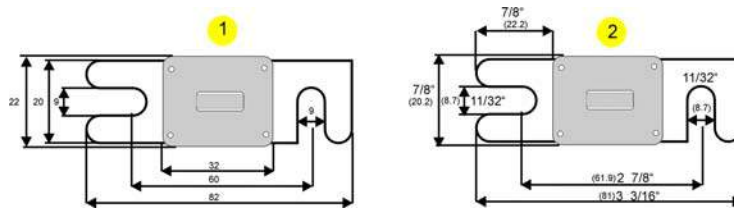


Figure 13. Dimensions for AC SuperDrive On-board Fuse.

1. Pudenze.
2. Buss (ANN series).

3.8.1 KEY START FUSE F2

Fuse F2 should be sized according to the number of AC SuperDrives in the circuit. Refer to Table 3 the current consumption of the KEY START input. Refer to Figure 11 for A CAN based Power Distribution.

3.8.2 INSTALLATION OF ON-BOARD FUSES

Each AC SuperDrive must be fused against internal faults and short circuits. Selection of appropriate fuse ratings is a system design issue. Consult the vehicle manufacturer’s maintenance documents for fuse size and ordering information. Figure 11 shows how to assembly on board fuse and motor connection.

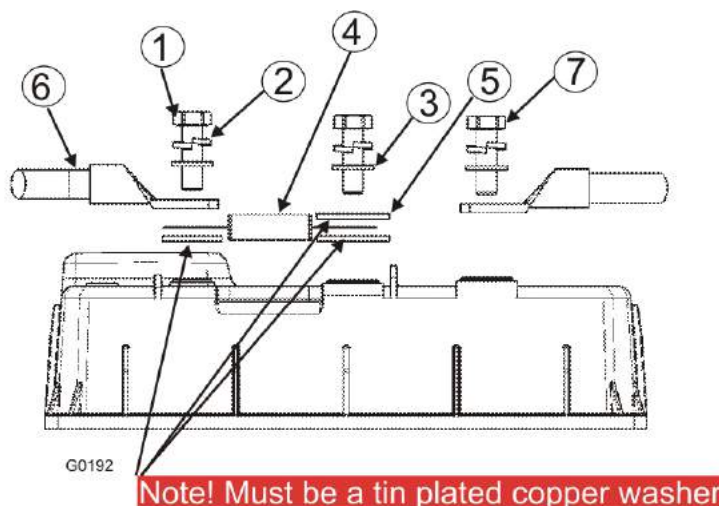



Figure 14. Recommended connection for on-board fuse and motor connection.

3.9 INRUSH CURRENT LIMITING RESISTANCE

	<p>CAUTION</p> <p>♦ The battery wiring to AC SuperDrives must include a suitable PTC (positive temperature coefficient) resistance or other provisions for limiting inrush current to the drive's filter capacitors during power up. Failure to limit inrush current may damage the drive.</p>
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During a cold start (when battery power is first applied via the disconnect switch), resistance in parallel with the main contactor provides limited current for charging the AC SuperDrive filter capacitors prior to energizing the main contactor. The resistance is comprised of a standard resistor in series with a PTC (Positive Temperature Coefficient) resistor. The PTC resistance serves to reduce current flow in the circuit in the event of a short circuit fault. In normal operation the filter capacitors have fully charged before the ohmic value of the PTC resistance changes significantly.

A diode in series with the PTC resistance prevents the energy stored in the SuperDrive's internal capacitors from powering the truck controller when the start key is switched off. See [Figure 11](#).

The configuration shown in [Figure 15](#) is typically used for Inrush Current Limiting for one (1) up to four (4) AC Superdrive.

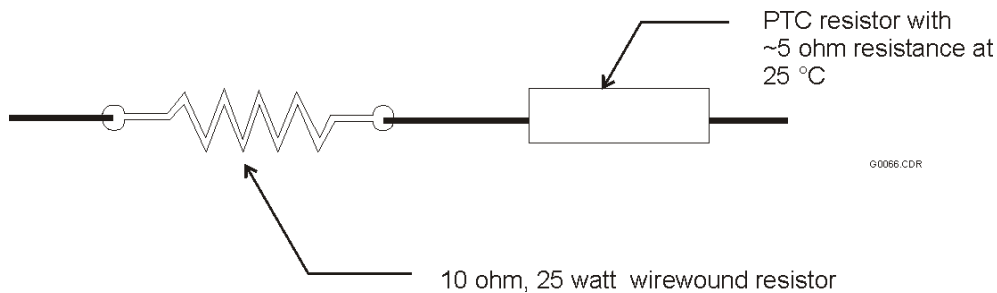


Figure 15. Recommended Inrush Current Limiting Circuit.

3.10 MAIN CONTACTOR

The main contactor functions as both a power distribution component and key component of the AC SuperDrive safety and protective interlocks circuit. The main contactor is energized when the AC SuperDrives 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 SuperDrive only after filter capacitors in each AC SuperDrive have charged.

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

$$I_{DC_IN} \text{ (DC Input current)} = \frac{\text{power output [kVA]}}{VBATT[VDC]}$$

i It is essential to protect the ACS against reversed battery polarity.

3.11 EMERGENCY STOP SWITCH

A manually operated Emergency Stop switch is usually included in the main contactor energization circuit. When activated, the Emergency Stop switch de-energizes the main contactor, removing battery power from the power conversion section of the AC SuperDrives.

i Note that removing power in this manner does not stop motion nor 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 vehicle motion in this situation.

3.12 KEY START INPUT

The KEY START input (see Table 3) supplies battery voltage to the AC SuperDrive for its internal processor and other functions. Power to the KEY START input is generally controlled by the vehicle start key.

3.13 CONTROL AND I/O CONNECTIONS

3.13.1 GENERAL

Connector K1 (Plug AMPseal 23P 770680-1, Contact 770854-1) provides the electrical interface for all control and I/O connections to an AC SuperDrive. Figure 16 illustrates wiring of the mating interface connector. Refer to Table 3 for a description of the control and I/O signals.

i Read AMP Application Specification 114-16016 for assembly instruction. <http://www.amp.com/>

K1 (pin)	Type	Name	Description
1	Input	KEY START	KEY START supplies battery voltage to the AC SuperDrive for its internal processor and other functions. Applying battery power initiates the drive power up sequence. This input should be fused for protection. Protected against reverse polarity Power = 15W
2, 10	Output	OPEN DRAIN OUTPUT 1 AND 2	One of the outputs may be utilized for controlling the main contactor in the system. ON (low) when AC SuperDrive is in normal operating mode. OFF (high) when a fault/error condition prevents normal operation. For inductive load, an external free wheel diode shall be used. Open Drain output, sinks 1A. The output is a PWM Controlled at 1, 2, 4, 8 kHz, or an ON/OFF output.

K1 (pin)	Type	Name	Description
3	Output	ENCODER +12_OUT	Supply for external motor pulse sensors. Diode in series for B+ protection. Output voltage 11V +-5% at 50mA load.
4	Output	ENCODER GND	Ground reference for ENCODER, not B+ protected.
5	Input	ENCODER CH 1	Phase 1 input from encoder (speed encoder). Internal 1 k Ω pull-up resistor to +12V_OUT
6	Input	ENCODER CH 2	Phase 2 input from encoder (speed encoder). Internal 1 k Ω pull-up resistor to +12V_OUT
11	Input	DIGITAL INPUT	Low<2V, High>8V, Max B+
12, 20	Output	ACS ID 1 AND 2	Internal Pull up See Table 5
13, 21	Output	ACS ID GND.	Not B+ protected. Ground reference for ACS ID. Use in first hand pin 13
16	Output	MOTOR TEMP	Sensor KTY 84 (Max 24V input).
17	Output	MOTOR TEMP GND	Not B+ protected. Ground reference for MOTOR TEMP GND
18	-	-	-
19	-	-	-
14, 15	Output	CAN_L	One for IN and one for OUT to the next device.
22, 23	Output	CAN_H	One for IN and one for OUT to the next device.
7, 8	Output	CAN GND.	One for IN and one for OUT to the next drive.
From November 2004			
9	Output	CAN 120R	CAN 120 ohm termination resistor. To use the termination connect pin 9 to 22.

Table 3. Interface Connector K1 Inputs and Outputs.

3.13.2 120 OHM TERMINATION

Both physical ends of the CAN Bus network shall be terminated with 120 Ω between CAN_H and CAN_L to improve noise immunity. Internally one end of the termination resistor is connected to CAN_L. The open end of the resistor is connected to pin 9, see [Table 3](#).

3.13.3 SPEED ENCODER SIGNALS

The speed encoder that is integrated into the motor, provides speed and direction feedback for the AC SuperDrive. The connector on the AC SuperDrive side is an AMP Superseal (282088-1). The standard speed encoder 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 accessible via CANopen).

K1	Signal name	Wire color	AMP Pin No	AMP Connector
3	ENCODER +12_OUT	Red	1	
4	ENCODER GND	Black	4	
5	ENCODER CH 1	Blue ¹⁾	2	
6	ENCODER CH 2	White ¹⁾	3	

Table 4. Standard Speed encoder Wiring Color-Codes.

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.

Speed encoders are manufactured with a short length of unshielded four conductor cable to which input and output connections are made. Table 4 lists the color-coding and signals names for the standard speed encoder. Figure 16 shows the wiring diagram.

i The motor connections (U, V, W) shall never be swapped.

The connector on the motor side is an AMP Superseal (282106-1) with integrated RC filter.

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.

i Contact the motor manufacturer to get the correct wiring; otherwise the characteristic for the sensor will be changed. There can be other connectors at motor side depending on OEM

3.13.4 ACS ID1 AND ID2 INPUTS

The ACS ID1 and ID2 inputs are used in applications to inform the AC SuperDrive firmware of it's function (i.e. whether a traction or lift). Connector(s) K1 pins 12 & 20 are wired as indicated in Table 5 to assign the function of each drive. The OEM can choose functions to adapt their own purpose. The CAN base address is default value 8 to 5, See Table 5. The ACS ID is accessible via CANopen

CANopen Default ID	ACS ID2 (K1:20)	ACS ID1 (K1:12)
8	1 (open)	1 (open)
7	1 (open)	0 (connected to ACS ID GND)
6	0 (connected to ACS ID GND)	1 (open)
5	0 (connected to ACS ID GND)	0 (connected to ACS ID GND)

Table 5. K1 Pin 12 & 20 Wiring verses AC SuperDrive Function.

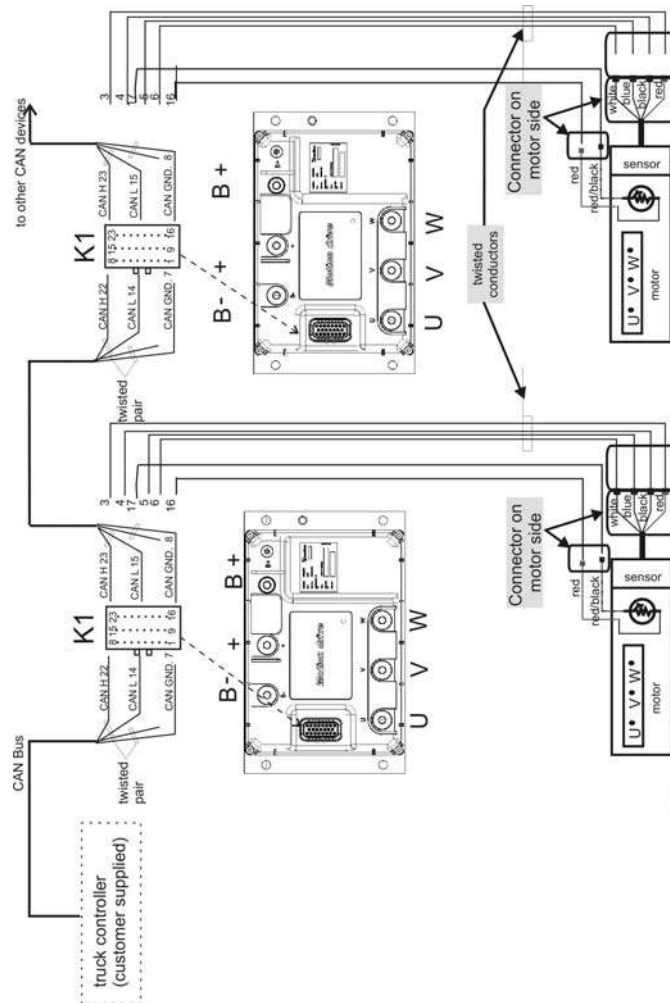


Figure 16. AC SuperDrive Control and I/O Wiring Diagram for SKF P/N 6206.

3.13.5 TEMPERATURE SENSOR

i Contact the motor manufacturer to get the correct wiring; otherwise the characteristic for the sensor will be changed. There can be other connectors at motor side depending on OEM

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 SuperDrive to monitor motor temperature. The connector on the AC SuperDrive side is an AMP Superseal (282080-1). Table 6 lists the color-coding and signal names for the standard motor temperature sensor. Figure 16 shows the wiring diagram.

The connector on the motor side is an AMP Superseal 282104-1 with integrated RC filter as standard.

The ACS temperature measurement has a constant current source, which runs 1.8mA through the temperature sensor. This results in a voltage that reflects the temperature. The motor temperature is accessible via CANopen.

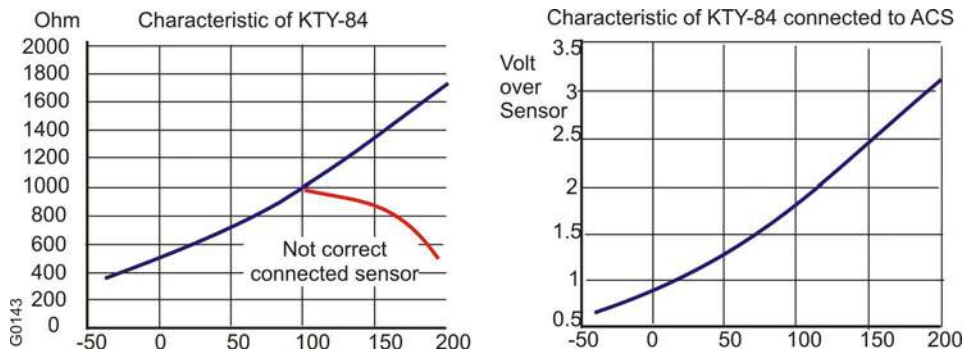


Figure 17. Characteristics of Temperature Sensor KTY-84.

K1	Signal name	Wire color	AMP Pin No	AMP Connector
16	MOTOR TEMP	Red.	2	
17	MOTOR TEMP GND	Red with a longitudinal black stripe.	1	

Table 6. Standard Motor Temperature Sensor Wiring Color Codes.

3.14 CAN BUS COMMUNICATIONS

i For additional information on CAN Bus and CAN hardware, refer to the Standard ISO 11898. The AC SuperDrive conforms to the CANopen software protocol

The AC SuperDrive employs an isolated CAN bus interface. Figure 18 illustrates the wiring configuration for:

- AC SuperDrive on a CAN network.
- VMC20

The CAN Bus must be wired in a “Daisy chain” arrangement as shown in Figure 18. 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 ACS). 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 18).

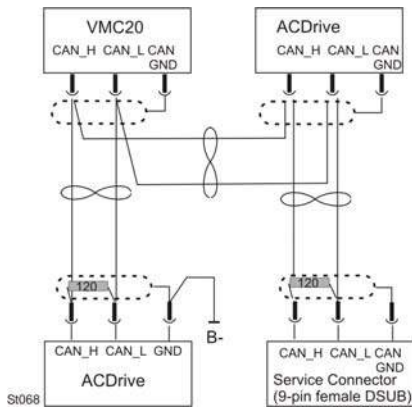


Figure 18. AC SuperDrive and VMC20 Connection to a Truck CAN Network (three isolated nodes).

If one unit on the CAN bus is non-isolated, no external connection of CAN GND shall be made. If several units on the CAN bus are non-isolated, these should all be grouped together at one end on the CAN bus, and the GND connection to these units should be taken from one common point (star connection) if possible (see Figure 19). Under no circumstances shall CAN GND be carrying supply current to any of the units, nor be connected to the frame of the truck.

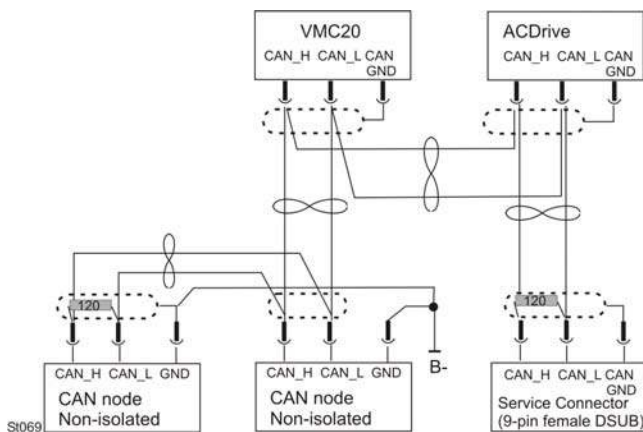


Figure 19. ACS SuperDrive and VMC20 Connection to a CAN Network (two isolated and two non-isolated nodes).

4 START UP & COMMISSIONING


4.1 GENERAL

The AC SuperDrive is a software configurable device. In a CAN (Controller Area Network) based system, all aspects of AC SuperDrive setup and operation are managed by a truck controller communicating over the CAN Bus.

This section presents a general procedure for the startup and verification of an AC SuperDrive following installation in an operational system (vehicle).

1 The initial startup and verification of an AC SuperDrive in a new application or new design requires additional steps which are detailed in 4.2.

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](#) beginning on page 69 provides procedures for pinpointing and eliminating the causes of warning and error conditions.

	<p>CAUTION</p> <ul style="list-style-type: none"> ◆ Wiring errors, improper setup, drive faults and other conditions may cause the vehicle to move in the wrong direction or at the wrong speed. Take necessary precautions to prevent injury to personnel or damage to equipment prior to applying power for the first time. ◆ Make sure that the motor and battery cables are connected correctly. Incorrect motor or battery connections may destroy the AC SuperDrive.
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4.2 CHECKS PRIOR TO INITIAL POWER UP

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

1. Verify that the proper AC SuperDrive item number for the application has been installed. Verify that the vehicle battery voltage matches the AC SuperDrive's Nominal DC Supply Voltage rating listed on the product identification label affixed to the AC SuperDrive (see [Figure 2](#)).
2. Verify that all power and signal wiring to the AC SuperDrive is correct.
3. Verify that the resistance (or other provisions) for limiting inrush current to the drive capacitors is properly installed in the power wiring to the AC SuperDrive.
4. Verify that connections to battery and motor terminals are tight.
5. Verify that the control I/O connector is fully mated and latched into position with the mating connector (K1) on the AC SuperDrive.
6. Verify that the AC SuperDrive is correctly fused for the application. Refer to the vehicle manufacturer's maintenance documentation for the correct fuse size
7. 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).

4.3 **VERIFYING AC SUPERDRIVE READINESS FOR OPERATION**

The following procedure is to verify that an AC SuperDrive 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 SuperDrives.
2. Verify that the green LED indicator on each AC SuperDrive 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 SuperDrive.
3. Consult the [Troubleshooting guide](#) beginning on page 69 of this manual for possible causes and corrective actions.


4.4 **CONFIGURING THE AC SUPERDRIVE FOR THE APPLICATION**

As shipped from us in the beginning of a truck development project, the AC SuperDrive is pre configured with a set of default parameters appropriate for the drive model and motor designated to be controlled by the AC SuperDrive. 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 SuperDrive start-up procedure is to update those AC SuperDrive parameters adjustable by the user to the values established for the application. The user-adjustable parameters are specified in [Configuration & control of the AC SuperDrive](#) at page 41.

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 SuperDrives. 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 SuperDrive'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 ACS.

The truck controller, by – for example – reading the checksum for all parameters stored in the AC SuperDrive'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 SuperDrive has been correctly configured.

	<p>WARNING</p> <ul style="list-style-type: none"> ◆ All AC SuperDrive 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 truck, for example braking, are working properly. ◆ The complete range of parameter values that are updated by the truck
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controller (or any other device) has also to be verified and validated prior to that the 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 truck's safety critical functions.

4.5 OPERATIONAL CHECKS IN VEHICLE



CAUTION

- ◆ For lift applications, make sure the pump rotates in the proper direction. Rotation in the wrong direction may damage the pump.
- ◆ Make sure that the motor and battery cables are connected correctly. Incorrect motor or battery connections may destroy the AC SuperDrive.

1. With the main contactor open (not enabled), apply battery power to the AC SuperDrive's B+ (or +) terminal through the inrush current limiting resistance.
2. Before enabling the main contactor, verify that the AC SuperDrive's filter capacitors have charged. The filter capacitors are fully charged when the voltage measured between the AC SuperDrive's + and B- terminals has reached battery voltage level.
3. Enable the main contactor.
4. Verify that the AC SuperDrive and it's associated motor start, stop and run properly at slow speed and at full operational speed. Refer to [Speed encoder signals](#) at page 29.

5 MAINTENANCE

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



The AC SuperDrive contains no user adjustable or user replaceable components beneath its protective cover. Do not remove the cover.

Do not clean the AC SuperDrive 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 SuperDrive, 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 SuperDrive from possible damage due to voltage transients, the AC SuperDrive's internal filter capacitors must be discharged as described in "Drive Removal" on page 40. Do not short the + to B- terminal.

5.1 PERIODIC PREVENTIVE MAINTENANCE

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

5.1.1 AC SUPERDRIVE WITH FINNED HEATSINK

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 heatsink and blades of the cooling fan (if applicable). If air is used, use only air with low pressure.
3. Make sure nothing is obstructing the drive's air circulation path.
4. Retighten the fastening screws on the AC SuperDrive to 10 Nm \pm 1Nm.
5. Retighten the bolts on the motor and battery terminal posts to 15 (\pm 2) Nm.
6. (If applicable) power up the AC SuperDrive and verify that the cooling fan is operational.

5.1.2 AC SUPERDRIVE FLAT HEATSINK

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 SuperDrive. If air is used, use only air with low pressure.
3. Retighten the bolts on the motor and battery terminal posts to 15 (± 2) Nm.
4. Retighten the bolts on the AC SuperDrive to 23 (± 2) Nm.

5.2 REPLACEMENT OF AC SUPERDRIVE

5.2.1 DRIVE REMOVAL

1. Remove all power from AC SuperDrive'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 on-board fuse (if applicable) for use in replacement drive.
6.
 - On units with fins, loosen four bolts securing drive to its mounting brackets.
 - On units with a flat heat sink, remove bolts securing drive to the vehicle.
Use the extra threaded holes to break loose the drive from the thermal grease. Then remove drive from the vehicle.

5.2.2 DRIVE INSTALLATION

1. Verify that battery power to the B+, + and key start inputs has been removed.
 2.
 - On units with fins, place the replaced drive on its mounting brackets.
See [Mounting AC SuperDrive with fins heatsink](#), on page 21
 - On units with a flat heatsink, clean the mounting surface before applying thermal grease on the unit before mounting. See [Mounting AC SuperDrive with flat heatsink](#), on page 22.
 3. Install the on-board fuse (if applicable), motor wires, battery wires and bolts. Tighten the nuts to 15 (+3 –0) Nm.
 4. Insert mating connector into K1.
- Perform initial start-up per the procedure titled [Start up & commissioning](#)

6 CONFIGURATION & CONTROL OF THE AC SUPERDRIVE

6.1 INTRODUCTION

An overview of the AC SuperDrive control is shown in [Figure 20](#), where the software blocks are non-filled and the hardware blocks are shaded gray.

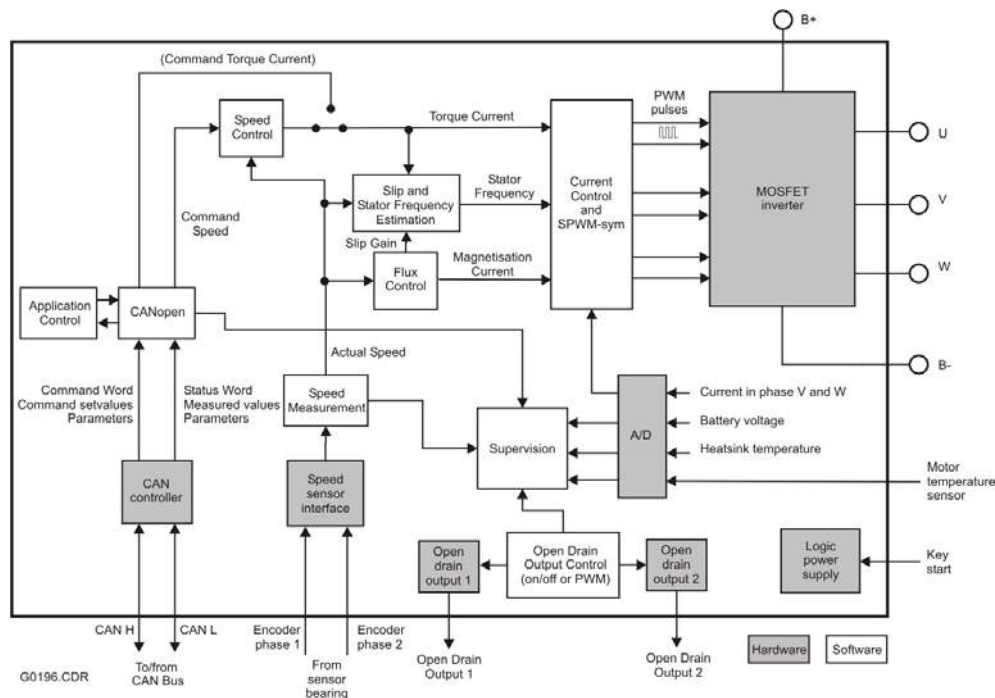



Figure 20. Overview of the AC SuperDrive control.

The functionality of the AC SuperDrive comes largely from its resident operating software, which controls nearly every aspect of its operation. The AC SuperDrives have no potentiometer or jumpers for setup or adjustments. Parameters and variables passed to the operating software perform these functions and characterize the drive's behavior. Parameters also define key characteristics of the controlled motor and define the operating envelope of the motor/drive combination.

A step in each new design is to establish the parameter values for the motor/drive in its application. This section presents guidelines and procedures for establishing parameter values. The parameter values established are thereafter normally used as default values in shipped AC SuperDrives. The exceptions are the following:

- The truck controller (or other device) downloads (via SDO(s)) parameter values that depend 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 SuperDrive's non-volatile memory (EEPROM). Thereafter the configuration is not changed until another configuration is downloaded and stored in the same manner.

- When parameters are continuously updated via the real time data exchange (PDO(s)) from the truck controller to the ACS.



WARNING

- ◆ All AC SuperDrive 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 truck, for example braking, are working properly.
- ◆ The complete range of parameter values that are updated by the truck controller (or any other device) has also to be verified and validated prior to that the 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 truck's safety critical functions.

6.2 CANOPEN AND APPLICATION CONTROL

The AC SuperDrive is controlled via the CAN bus by the use of CANopen. By passing a PDO regularly to the ACS with a constant frequency, the speed of the motor and the status of the ACS can be controlled. In its basic configuration the Command Word and the Command Speed is sent to the ACS via this Receive PDO. The ACS then returns a Transmit PDO regularly that at least includes the Status Word and the Actual Speed.

The Command Word is a bit field and by clearing/setting a bit, the operational characteristics of the ACS are changed. The Status Word is also a bit field and it reflects the actual status of the ACS. The Command Word and the Status Word are described in [Table 7](#).

Index	Sub-Index	Name	Description
2000h	1	Command Word	Bit 0 Switch On (Close main contactor, if used) Bit 1 Speed Neutral Brake Ramp Parameter Set LSB Bit 2 Speed Neutral Brake Ramp Parameter Set MSB Bit 3 Enable Operation (Enable power stage) Bit 4 Speed PI Controller Parameter Set LSB Bit 5 Reserved Bit 6 Open Drain Output 1 On Bit 7 Open Drain Output 2 On Bit 8 Capacitor Discharge On Bit 9 Rollback Disable Bit 10 Reserved Bit 11 Speed Ramp Parameter Set LSB Bit 12 Speed Ramp Parameter Set MSB Bit 13 Foot Brake On Bit 14 Magnetisation Current Low On Bit 15 BDI Magnetisation Current Pulse Enable (Option)

Index	Sub-Index	Name	Description
2001h	1	Status Word	Bit 0 Ready To Switch On (Dc bus is charged) Bit 1 Switched On (Main contactor, if used, is on) Bit 2 Operation Enabled (Power stage is enabled) Bit 3 Error Bits 4-5 Reserved Bit 6 Switch On Disabled (Dc bus voltage to low, charging timeout) Bit 7 Warning Bit 8 Regeneration (Power flow is from ACS to battery) Bit 9 Speed Sensor Warning Active Bit 10 BDI Magnetisation Current Pulse Enabled (Option) Bit 11 Linear Current Rollback Active Bit 12 Open Drain Output 1 On Bit 13 Open Drain Output 2 On Bit 14 Foot Brake Active Bit 15 Default Parameters

Table 7. The Command Word and the Status Word.

The sequence to initiate the CANopen communication and to enable the operation of the ACS is described in the following:

1. Send the NMT message Start Remote Node to the ACS. The CANopen state of the ACS will become OPERATIONAL. Prior to this it is however possible to use the SDO object in order to configure ACS parameters.
2. Start up the PDO objects, i.e. start sending the PDO to the ACS (PDO1Rx) and start receiving the PDO from the ACS (PDO1Tx). If the SYNC object is used then also start to send that. The transmit period of PDO1Rx and SYNC, if used, shall be between 8 to 20 ms. The transmit period of the PDO1Tx in the ACS depends on the Transmission Type.

If a second PDO is used, i.e. PDO2Rx and/or PDO2Tx, this service shall also be started.

Note: Once the CANopen state of the ACS becomes OPERATIONAL (via the NMT message Start Remote Node), PDO communication must start within one second. Once the first PDORx is received, subsequent PDORx's must be received at an interval not longer than specified by the PDO Timeout parameters (Index 5F04h:3-4). The SYNC object, if used, must occur at an interval not longer than specified by the Sync Timeout parameter (Index 5F04h:2).

3. Wait until the bit Ready To Switch On (Bit 0) is set in the Status Word, i.e. the Dc Bus is charged. Then the bit Switch On (Bit 0) in the Command Word shall be set and this even if the main contactor mode is not used. The ACS confirms this by setting the bit Switched On (Bit 1) in the Status Word. Clearing the bit Switch On does not change the status of the ACS, i.e. the bit Switched On cannot be reset if it has been set.
4. At the same time or after the bit Switch On is set, it is possible to enable the ACS by setting the bit Enable Operation (Bit 3) in the Command Word. The ACS confirms this by setting the bit Operation Enabled (Bit 2) in the Status Word.
5. The ACS can be disabled at any time by clearing the bit Enable Operation in the Command Word. The ACS confirms this by resetting the bit Operation Enabled in the Status Word. If the automatic drive disable function is enabled (see Index 2020h:9), the Operation Enabled bit is reset when this function disables the ACS power stage.
6. If an Error condition occurs, the ACS is disabled and this is reflected in that the bit Operation Enabled is cleared at the same time as the bit Error is set in the Status Word. The ACS also sends an EMCY message.

7. In order to restart the ACS when an error condition has occurred, the NMT message Reset Node has to be sent. After that the procedure from point 1 and forward has to be repeated. A restart of the ACS can also be done by turning off and then turning on the Key Start voltage in the connector K1.

6.3 SPEED MEASUREMENT

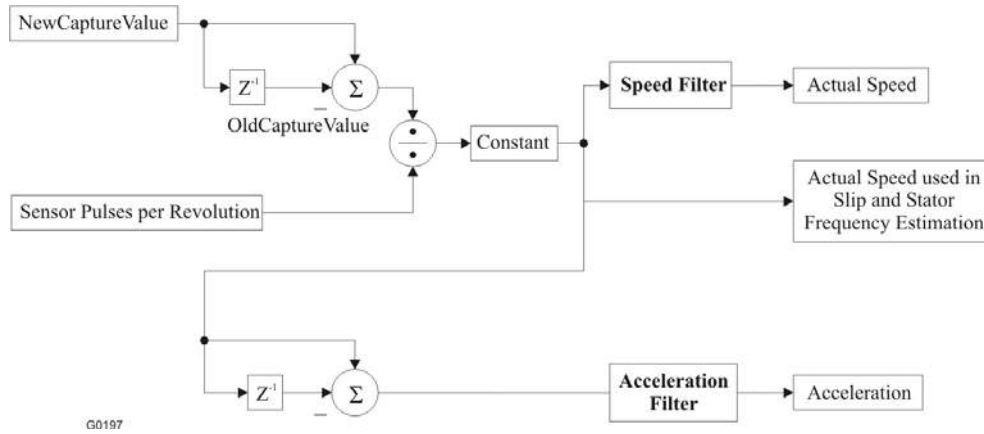


Figure 21. Speed Measurement.

Index	Sub-Index	Name	Description
2050h	4	Sensor Pulses per Revolution	Usually 64 or 80.
2050h	2	Speed Filter Gain	First order filtering coefficient for the speed used in the speed control. FilteredValue = FilteredValue-FilterGain/256* (RawValue-FilteredValue) Filter gain = 256 means no filtering.
2050h	5	Acceleration	Read only variable (rpm/20ms).

Table 8. Speed Measurement – Parameters.

6.3.1 TUNING OF SPEED MEASUREMENT

The parameter Sensor Pulses per Revolution is given by the AC motor used. For the other Speed Measurement parameters (Table 8), the defaults values are optimum for the majority of applications and do normally not require further adjustment.

6.4 SPEED CONTROL

The speed controller is shown in [Figure 22](#) and consists of three main blocks, namely Speed Ramp, Best Performance Curve^{Option} and Speed PI Control. The Command Speed is the input to the speed controller and the limited Torque Current is the output. It is also possible to disable the speed controller and use torque control instead. The input then is the Command Torque Current.

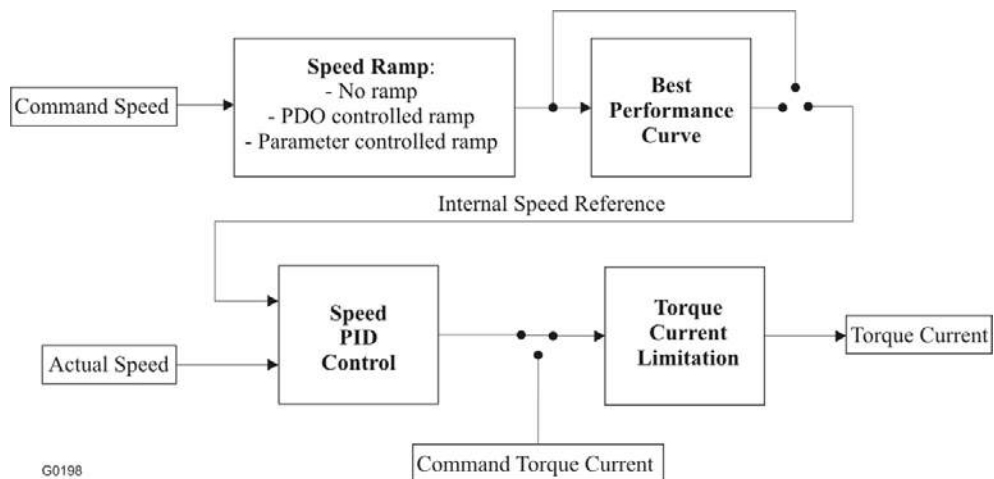


Figure 22. Speed Control.

There are four different speed control modes:

- No ramp
- PDO controlled ramp
- Parameter controlled ramp
- Torque control (speed control disabled)

Common parameters and variable for the top three speed control modes are shown in [Table 9](#) (for torque control it is only the parameter Speed Control Mode that is of interest).

Index	Sub-Index	Name	Description
2020h	1	Speed Control Mode	1 = Speed control with no ramp 2 = Not valid 3 = Torque control (Speed control disabled) 4 = Speed control with PDO controlled ramp 5 = Speed control with parameter controlled ramp
2020h	6	Best Performance Curve Mode (Option)	0 = No BPC mode (BPC disabled) 1 = BPC mode 2 = BPC PDO mode 3 = BPC Reduction Mode
2020h	9	Automatic Drive Disable Time	0-255s Time before drive is disabled after standing still. Setting the parameter to zero means no automatic disabling.
2020h	10	Application Setup Word	Bit 3 Inverted Rotational Direction False or True.
2090h	1-2	Speed PI Controller: P-gain Set 0-1	
2091h	1-2	Speed PI Controller: I-gain Small Set 0-1	Speed Control Mode = 1: Always used Speed Control Mode = 4 or 5: During constant speed and acceleration
2092h	1-2	Speed PI Controller: I-gain Medium Set 0-1	Speed Control Mode = 1: Not used Speed Control Mode = 4 or 5: During rollback
2093h	1-2	Speed PI Controller: I-gain Large Set 0-1	Speed Control Mode = 1: Not used Speed Control Mode = 4 or 5: During standing and deceleration
2096h	1	Internal Speed Reference	Read only variable. Speed reference input to speed PI controller (internal SW variable). Differs from Command Speed when ramps and/or BPC is used.

Table 9. Speed Control – Parameters and Variables.

6.4.1 SPEED RAMP

The Speed Ramp functionality is mainly described for the traction application but of course the ramp functionality can be utilized also for the lift application.

6.4.1.1 GENERAL

The purpose of using a ramping of the Command Speed is to get a smooth acceleration/deceleration, save battery lifetime and give the truck equal stop distance regardless of load and slopes when decelerating. The speed ramp functionality is implemented before the speed PI control, as can be seen in [Figure 22](#). There are a number of parameters that can be set for controlling the behavior of the ramp:

Index	Sub-Index	Name	Description
2020h	1	Speed Control Mode	4 = Speed control with PDO controlled ramp 5 = Speed control with parameter controlled ramp
2020h	7	Rollback Speed	0-8000 rpm Controls if the truck stands still or starts rolling when slowing down to zero speed in an slope. Setting the speed to zero means stand still (hillhold). Only used in speed control modes with ramps (Speed Control Mode = 4 or 5).
2020h	10	Application Setup Word	Bit 0 Adjust Speed During Acceleration If set to true, the truck may accelerate faster than the ramp says, if accelerating in an steep downhill slope. Bit 1 Adjust Speed During Deceleration If set to true, the truck may decelerate faster than the ramp says, if decelerating in an steep uphill slope. Bit 2 Enter Rollback Mode At Zero Speed If set to true, the truck stops before it eventually starts to roll. Only used if Rollback Speed is NOT zero
2095h	9	Speed Change Shift Factor	Righth shift of Acceleration/Deceleration values. Changes the scale of the ramps, i.e. from: 0->255 rpm/20ms to: (0->255)/2 ⁿ rpm/20ms where n = Speed Change Shift Factor
2096h	4	Used Max Forward Acceleration	Read only variable.
2096h	5	Used Max Forward Deceleration	Read only variable.
2096h	6	Used Max Reverse Acceleration	Read only variable.
2096h	7	Used Max Reverse Deceleration	Read only variable.

Table 10. Speed Ramp – Parameters and Variables.

6.4.1.2 BASICS

The basic speed ramp functionality is shown in [Figure 23](#). When a step change in the Command Speed is sent to the ACS the Internal Speed Reference value is ramped from the previous Internal Speed Reference speed value to the new Internal Speed Reference.

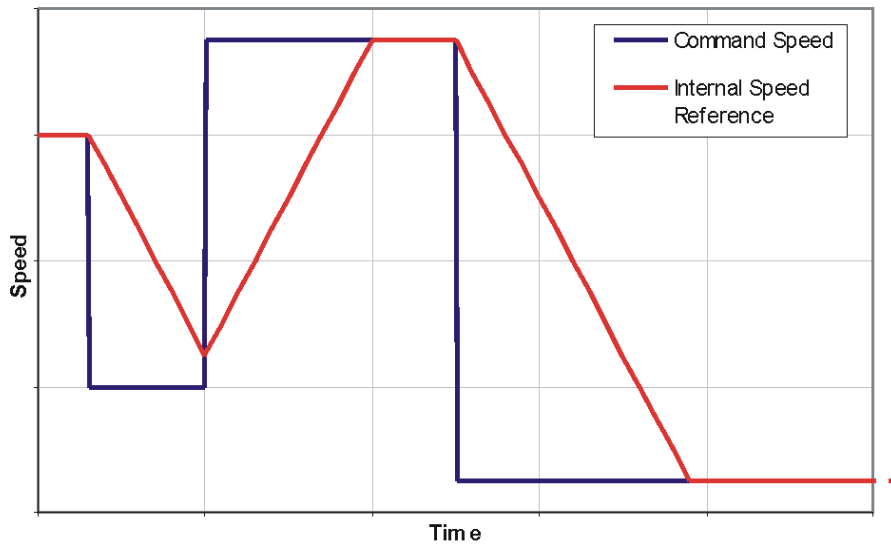


Figure 23. The basic speed ramp.

6.4.1.3 SLOPES

In case of braking or slowing down in an uphill slope the gravitation will contribute to the deceleration. If the slope is steep the truck will slow down faster than the Internal Speed Reference. In order to allow the truck to decelerate faster than the ramp, the ramp is adjusted to the actual speed when decelerating in a steep slope as can be seen in Figure 24. This functionality is possible to enable or disable with bit 1 (Adjust Speed During Deceleration) in Application Setup Word (2020h:10).

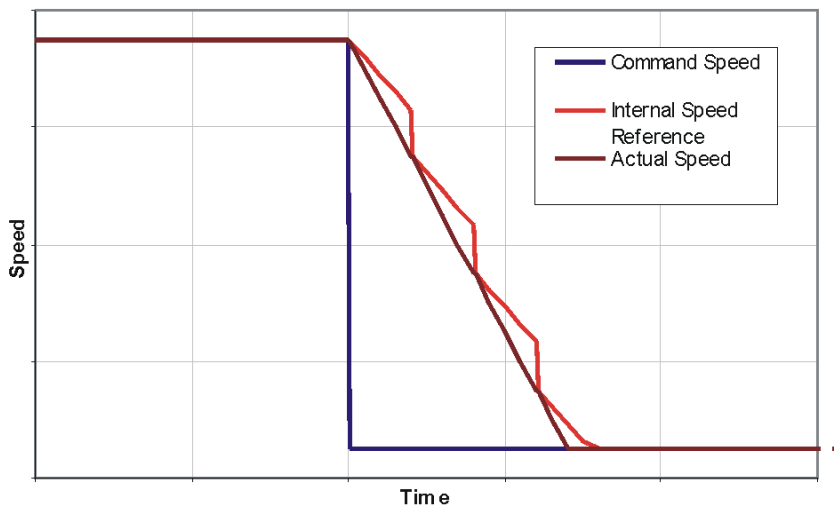


Figure 24. Adjustment of deceleration ramp when braking in an uphill slope.

In case of acceleration in an downhill slope the gravitation will contribute to the acceleration. If the slope is steep the truck will accelerate faster than the Internal Speed Reference. In order to allow the truck to accelerate faster than the ramp, the ramp is adjusted to the actual speed when accelerating in a steep slope. This functionality is possible to enable or disable with bit 0 (Adjust Speed During Acceleration) in Application Setup Word (2020h:10).

6.4.1.4 ROLLBACK

When slowing down to zero speed in a slope, the truck can either continue to stand still or start rolling. The parameter used to control the behavior is called the Rollback Speed (2020h:7 in object dictionary). Setting this parameter to zero means that the truck will stand still after slowing down. If the Rollback Speed is set > 0 the truck will continue rolling after slowing down. In a downhill slope the truck will either reach zero speed or not depending on bit 2 (Enter Rollback Mode At Zero Speed) in Application Setup Word. After slowing down the truck will continue rolling with a speed larger than zero but less than or equal the Rollback Speed. Since an accelerating torque is not allowed the speed will be lower than the Rollback Speed if the slope is flat. In an uphill slope the truck will reach zero speed and then start rolling backwards down the slope with a speed larger than zero but less than or equal to the Rollback Speed value.

The bit 9 (Rollback disable) in the Command Word can be used to override the Rollback Speed parameter, i.e. the rollback functionality becomes disabled if the bit is set.

6.4.1.5 NO RAMP

In the No Ramp mode, the speed ramp controller is not used and only the speed PI controller is used. The byte-oriented receive PDO should at least include the Command Word and the Command Speed according to Table 11.

1	2	3	4	5	6	7	8
Command Word		Command Speed		Optional			

Table 11. No Ramp – Receive PDO contents.

Bit 4 and 5 in the Command Word are used to choose 1 out of 4 possible parameter sets that is to be used in the speed PI control.

6.4.1.6 PDO CONTROLLED RAMP

In the PDO Controlled Ramp mode, all ramp information is sent inside the PDO, which should have the following contents.

1	2	3	4	5	6	7	8
Command Word		Command Speed		Command Acceleration	Command Deceleration	Optional	

Table 12. PDO controlled ramp - Receive PDO contents.

The Command Acceleration (byte 5) and the Command Deceleration (byte 6) are the ramp values (0-255 rpm/20ms). The Command Word uses the same bits as for No Ramp mode to control the parameter set in the speed PI controller, i.e. bit 4 and 5 in the Command Word. Functionality as reverse brake (plug brake), neutral brake and foot pedal brake are to be handled within the truck computer.

6.4.1.7 PARAMETER CONTROLLED RAMP

In the Parameter Controlled Ramp mode, the ramp is controlled from the PDO but the actual ramp values are given by parameters (accessible via SDOs). The PDO has exactly the same contents as for No Ramp Mode, except that five extra bits are used in the Command Word (Table 12).

Bit	Description
1-2	Speed Neutral Brake Ramp Parameter Set (0-3). See object indexes 2104h - 2105h.
11-12	Speed Ramp Parameter Set (0-3). See object indexes 2100h - 2103h.
13	Foot Brake Active, 1 = True.

Table 13. Parameter Controlled Ramp - Command Word.

In order to improve the ramp functionality it is also possible to include the parameters 2000h:7 and 2000h:8 shown in Table 15 in the PDO. The receive PDO then looks as in Table 14.

1	2	3	4	5	6	7	8
Command Word		Command Speed		Acceleration Reduction Factor	Max Speed Reduction Factor	Optional	

Table 14. PDO controlled ramp - Receive PDO contents.

Index	Sub-Index	Name	Description
2000h	7	Acceleration Reduction Factor	UsedAcceleration = Acceleration * AccelerationReductionFactor / 128 AccelerationReductionFactor = 128 means no reduction.
2000h	8	Max Speed Reduction Factor	Reduction of parameter Max Speed that is used during Reverse Brake. UsedMaxSpeed= MaxSpeedInRpm*(MaxSpeedReductionFactor+1)/256 MaxSpeedReductionFactor = 255 means no reduction.
2120h	1	Max Speed	Used during Reverse Brake.

Table 15. Parameter Controlled Ramp – Parameters.

There are a total of four speed ramp parameters used in four editions, namely Forward Acceleration, Forward Deceleration, Reverse Acceleration and Reverse Deceleration.

There are also a total of six special speed ramp parameters used in two editions, namely Special Forward Deceleration and Special Reverse Deceleration.

These speed ramp parameters are used during accelerations and decelerations according to descriptions in [Table 16](#).

Index	Sub-Index	Name	Description
Forward Acceleration (2100h) and Reverse Acceleration (2102h)	1	Parameter Set 0	Used according to bits 11-12 in the Command Word.
	2	Parameter Set 1	
	3	Parameter Set 2	
	4	Parameter Set 3	
Forward Deceleration (2101h) and Reverse Deceleration (2103h)	1	Parameter Set 0	Used according to bits 11-12 in the Command Word if Command Speed < Actual Speed and Command Speed ≠ 0 and has the same sign as the Actual Speed.
	2	Parameter Set 1	
	3	Parameter Set 2	
	4	Parameter Set 3	
Special Forward Deceleration (2104h) and Special Reverse Deceleration (2105h)	1	Foot Brake	Used if bit 13 in the Command Word is set.
	2	Reverse Brake	Used if Command Speed has the opposite sign of Actual Speed. UsedDeceleration = NeutralBrake + (ReverseBrake - NeutralBrake) * CommandSpeed / UsedMaxSpeedInRpm
	3	Neutral Brake Set 0	Used according to bits 1-2 in the Command Word if Command Speed = 0.
	4	Neutral Brake Set 1	
	5	Neutral Brake Set 2	
	6	Neutral Brake Set 3	

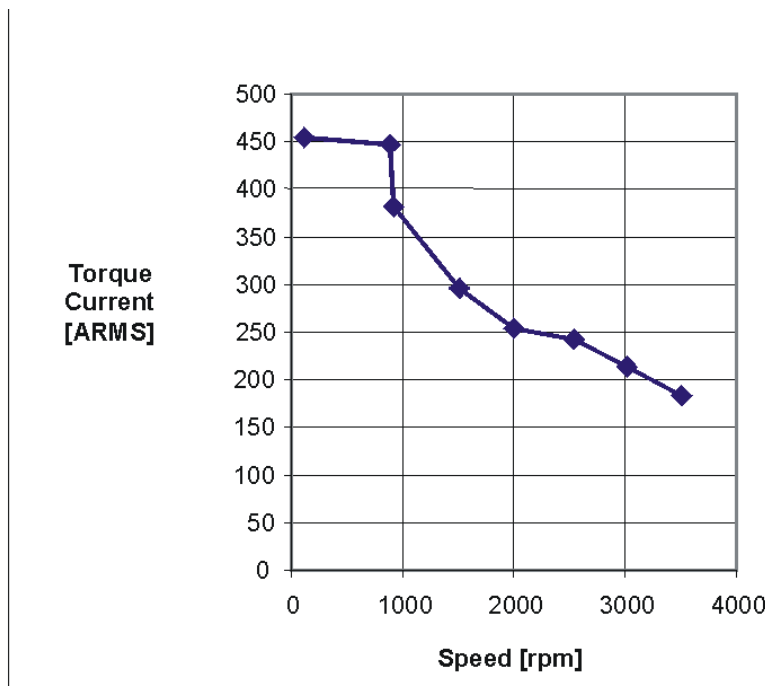
Table 16. Parameter Controlled Ramp - Ramp Parameters.

6.5 **BEST PERFORMANCE CURVE** ^{OPTION}

6.5.1.1 GENERAL

The Best Performance Curve functionality is implemented after the Speed Ramp and before the Speed PI controller, as can be seen in the [Figure 22. Speed Control](#). The purpose of the Best Performance Curve, or the 8-point curve as it also is called, is to save battery lifetime and get an optimal efficiency out of the ACS-motor system. The Best Performance Curve limits the torque (i.e. Torque Current) as a function of the motor speed (Actual Speed).

An example of a Best Performance Curve is shown in [Figure 25](#). 8 points specify the curve and between the points a linear interpolation is used. A Torque Current and a Speed give each point.



G0155

Figure 25. Best Performance Curve ^{Option}.

6.5.2 SPEED PI CONTROLLER

The Speed PI controller is a normal PI controller with two inputs, the Internal Speed Reference and the Actual Speed, and one output, the Torque Current. Depending on if speed ramps are used or not the PI controller works a bit differently. If no ramps are used, there is only one I-gain used (one for each parameter set). If ramps are used, there are a total of three I-gains (three for each parameter set). This is summarized in [Table 9](#) where also the other parameters that apply for the Speed PI Controller are described.

6.6 **TORQUE CURRENT LIMITATION**

The amplitude and derivate of the unlimited Torque Current, which is the output of the Speed PI controller, is checked and if necessary limited in the Torque Current Limitation block (see [Figure 22](#)).

The speed and the torque have the same sign if power is fed from the ACS to the motor. If the speed and the torque have opposite signs, the power is fed from the motor to the ACS (regeneration). From that follows that if the Actual Speed and the Torque Current has the same sign, the maximum amplitude is given by the parameter Max Acceleration Torque Current in [Table 17](#). With opposite signs on the Actual Speed and the Torque Current, the maximum amplitude is given by the parameter Max Brake Torque Current.

The derivate of the Torque Current is limited in order to avoid noise and unnecessary wear in couplings and gearboxes. The maximum allowed Torque Current derivate is controlled with the parameter Max Torque Current Change.

Index	Sub-Index	Name	Description
2095h	1	Max Acceleration Torque Current	Sets both Forward and Reverse Max Acceleration Torque Currents to the same value. Unit: ARMS
2095h	2	Max Brake Torque Current	Sets both Forward and Reverse Max Brake Torque Currents to the same value. Unit: ARMS
2095h	3	Max Torque Current Change	Unit : deciARMS/ms
2095h	5	Forward Max Acceleration Torque Current	Unit : ARMS
2095h	6	Reverse Max Acceleration Torque Current	Unit : ARMS
2095h	7	Forward Max Brake Torque Current	Unit : ARMS
2095h	8	Reverse Max Brake Torque Current	Unit : ARMS

Table 17. Torque Current Limitation – Parameters.

6.6.1 TUNING OF SPEED CONTROL

Tuning of parameters in the Speed Control determines the response characteristics for the AC SuperDrive's Speed Control.

6.6.1.1 TUNING IN PARAMETER OR PDO CONTROLLED RAMP MODE

With Speed Control Mode equal to Parameter or PDO Controlled Ramp mode, the optimum response for various operating conditions (i.e. slow speed, high speed, braking, holding) is mainly tuned with the acceleration and deceleration values, i.e.

- PDO Controlled Ramp: Command Acceleration and Command Deceleration that are set by the truck controller.
- Parameter Controlled Ramp: Ramp Parameters in [Table 16](#).

The values to be used are normally determined by the operating requirements for the vehicle.

Usually it is not necessary to utilize the four sets of Speed PI Controller parameters, which means that Set 0 can be used all time. It means that bit 4 and 5 in the Command Word should be equal to zero. The default Speed PI Controller parameters (P-gain, I-gain (Small, Medium and Large) are near optimum for the majority of applications and normally do not require further adjustment. However, optimum values can be established empirically by

alternately adjusting a parameter and operating the vehicle until the desired “feel” or response is achieved. Some general tuning guidelines follow.

- Speed PI Controller P-gain Set 0-3 (2090h:1-4) : Should be increased gradually from the default value until the vehicle's response to operator controls is acceptable. Excessively high P-gain can cause instability and excessive power consumption.
- Speed PI Controller I-gain (Small, Medium and Large) Set 0-3 (2092h-2093h:1-4) : The I-gain is typically used to increase sensitivity to small changes in operator controls when at or near zero speed. I-gain, in combination with P-gain, is beneficial for holding zero speed or to overcome friction when starting. Excessive I-gain can cause the motor/load to break into oscillation. I-gain should not be introduced until P-gain has been adjusted and the motor/load exhibits stable operation. It should be observed that there are three I-gains (Small, Medium and Large) that are used in PDO and Parameter Controlled Ramp modes. Table 9 explains during which operation conditions the Small, Medium and Large I-gain, respectively, are used.

The Torque Current Limitation parameters (Table 17) also have to be set to appropriate values so that optimum response for various operating conditions is achieved. It is also possible to get dynamic torque limit adjustability during operation by including the parameter Max Acceleration Torque Current in the PDO.

6.6.1.2 TUNING IN NO RAMP MODE

In No Ramp mode the four sets of Speed PI Controller parameters that are provided can be utilized. The truck controller can dynamically select the optimum response for various operating conditions (i.e. slow speed, high speed, braking, holding). The bit 4 and 5 in the Command Word are used to choose 1 out of the 4 possible parameter sets that is to be used in the speed PI control. Optimum values for the Speed PI Controller parameters are usually established empirically by alternately adjusting a parameter and operating the vehicle until the desired “feel” or response is achieved (see tuning guidelines in Tuning in parameter or PDO controlled ramp mode). It should be observed that in the No Ramp mode only the small I-gain is utilized (see Table 9).

6.7 FLUX CONTROL

6.7.1 BASICS

In the Flux Control, the Slip Gain used in the Slip Frequency Estimation and the Magnetization Current are computed as illustrated in Figure 26. The rotor flux in the motor is controlled via the Magnetization Current. The Magnetization Current (i.e. the rotor flux) is kept constant up to the Base Speed. Above the Base Speed, the Magnetization Current is reduced. Since the Slip Gain is reciprocally proportional to the Magnetization Current, the Slip Gain is increased above Base Speed. The Base Speed itself is proportional to the Dc Bus Voltage. It should also be observed that the Slip Gain is compensated with the Motor Temperature.

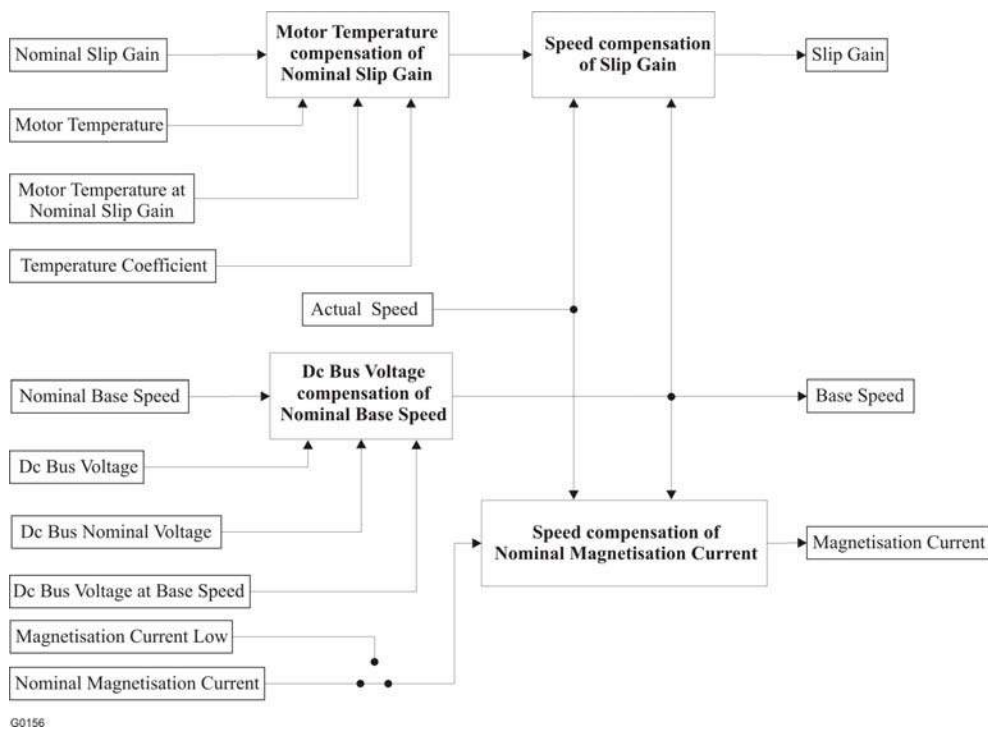


Figure 26. Flux Control (Slip Gain and Magnetization Current control).

6.8 PARAMETERS

The object indices for the parameters used within the Flux Control are described in [Table 18](#).

Index	Sub-Index	Name	Description
2070h	4	Nominal Base Speed	Nominal base speed in rpm for the motor connected to the ACS. The motor manufacturer or Danaher Motion usually supplies this parameter.
2070h	26	DcBus Voltage at Base Speed	In percentage of nominal dc bus voltage.
2070h	7	Nominal Slip Gain	Nominal slip gain for the motor connected to the ACS. The motor manufacturer or Danaher Motion usually supplies this parameter. 1 = 0.0000828 rad/s/ARMS or 0.0000132 Hz/ARMS
2070h	20	Motor Temperature at Nominal Slip Gain	The temperature in °C at which the Nominal Slip Gain is measured/calculated. The motor manufacturer or Danaher Motion usually supplies this parameter.
2070h	21	Temperature Coefficient	Rotor resistance percent change per 100 °C change in rotor temperature. The motor manufacturer or Danaher Motion usually supplies this parameter.
2070h	2	Nominal Magnetization Current	Nominal magnetization current for the motor connected to the ACS in ARMS. The motor manufacturer or Danaher Motion usually supplies this parameter.
2070h	40	Magnetisation Current Low	Turned on via bit 14 in the Command Word. Used for example at standstill and/or low load conditions in order to decrease the magnetisation current (i.e. reduce the losses in the motor).

Table 18. Flux Control - Parameters.

The [Table 19](#) describes the object indices of the variables (read only) within the Flux Control that are accessible via CANopen.

Index	Sub-Index	Name	Description
2070h	27	Base Speed	Dc Bus Voltage compensated Nominal Base Speed in rpm.
2070h	10	Slip Gain	Commanded slip gain 1 = 0.0000828 rad/s/ARMS or 0.0000132 Hz/ARMS. Temperature and speed compensated. Updated every 20 ms (50 Hz).
2070h	9	Magnetization Current	Commanded magnetization current in ARMS. Updated every 20 ms (50 Hz). The same as IdRef.

Table 19. Flux Control - Variables

6.8.1 TUNING OF FLUX CONTROL

For efficiency, performance and protection of the motor, these parameters must be correct. Danaher Motion can provide support and assistance in optimizing these parameters for the application.

6.9 SLIP AND STATOR FREQUENCY ESTIMATION

The Slip Speed and the Stator Frequency is estimated in the Slip and Stator Frequency Estimation. The Slip Speed is computed from the Slip Gain and the Torque Current as shown in Figure 27. The Stator Frequency that is integrated in the Current Control to get the Transformation Angle is computed as the sum of the Actual Speed (electrical) and the Slip Speed.

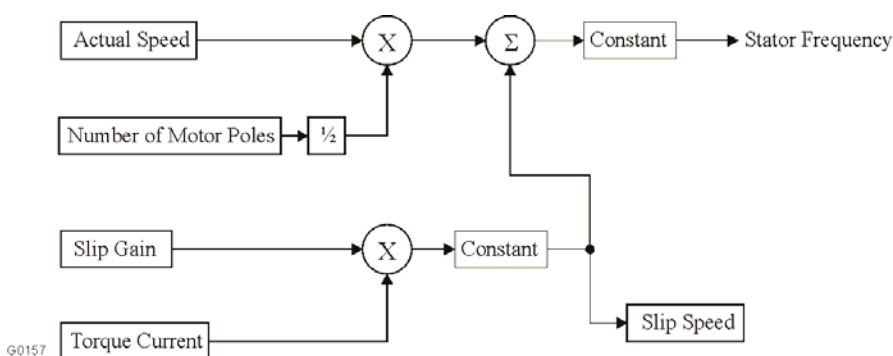


Figure 27. Slip and Stator Frequency Estimation.

6.9.1 PARAMETERS AND VARIABLES

The Number of Motor Poles is the only parameter that is configurable in the Slip and Stator Frequency Estimation (Table 20).

Index	Sub-Index	Name	Description
2070h	8	Number of Motor Poles	Number of motor poles from motor nameplate.

Table 20. Slip and Stator Frequency Estimation - Parameter

In Table 21 the object index of the variable Slip Speed (read only) that is accessible via CANopen is described.

Index	Sub-Index	Name	Description
2070h	11	Slip Speed	Difference between rotor speed and stator speed in rpm (mechanical difference speed).

Table 21. Slip and Stator Frequency Estimation - Variable

6.9.2 TUNING OF THE SLIP AND STATOR FREQUENCY ESTIMATION

The Number of Motor Poles is given by the motor manufacturer's nameplate data and specifications. Usually equal to 4 or 6.

6.10 CURRENT CONTROL

6.10.1 BASICS

A simplified scheme of the current control is shown in [Figure 28](#). The dq-plane implemented current controller (so called vector control) controls the magnetization current and the torque producing current independently of each other.

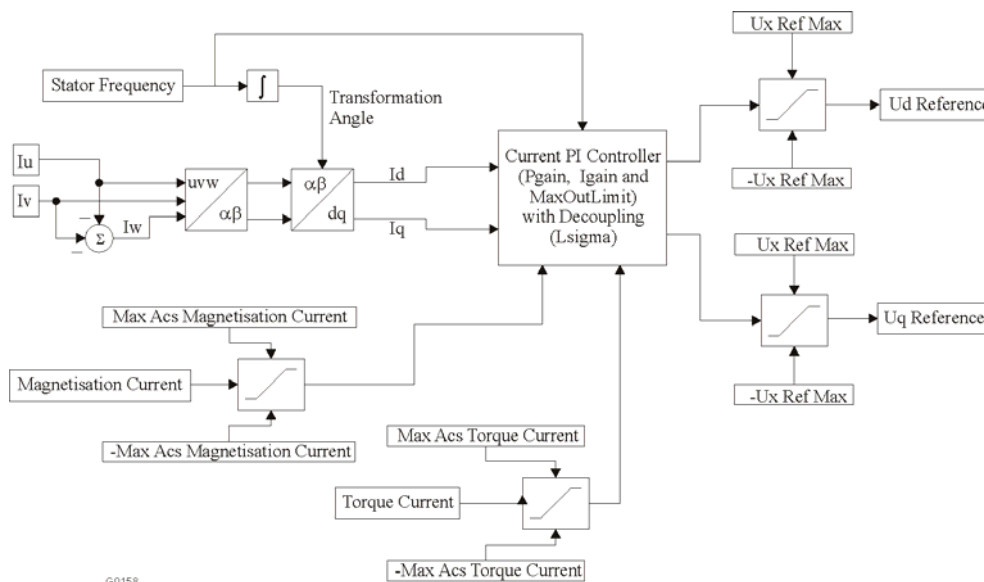


Figure 28. Simplified scheme of the Current Control.

The Magnetization Current (reference) is the output from the Flux Controller and the Torque Current (reference) is the output from the Speed Control. The Magnetization Current is checked against the constant Max Acs Magnetization Current in order to avoid damage of the drive if a too high magnetization current is set via the CANopen object dictionary.

From the measured current in phase U and V, the current in phase W is computed based on that the sum of the phase currents is zero. The measured current is then transformed to the $\alpha\beta$ -plane and thereafter follows a transformation to the rotating dq-plane. The Transformation Angle equals the integral of the stator frequency (i.e. stator angular frequency) and it is equal to the position of the rotor flux, i.e. the control is rotor flux oriented. The stator frequency is computed as the sum of the rotor frequency and the slip frequency in the Slip and Stator Frequency Estimation block (see [Figure 27](#)).

The measured currents in the dq-plane, I_d (measured magnetization current) and I_q (measured torque current), are then fed to the Current PI Controller with Decoupling together with the reference currents and the stator frequency. The reference voltages, U_d Reference and U_q

Reference, which are the outputs from the current control, are then limited to the voltage U_x Ref Max before they are handled by the SPWM-sym block.

6.10.2 PARAMETERS AND VARIABLES

The object indices for the parameters used within the Current Control are described in [Table 22](#)

Index	Sub-Index	Name	Description
2070h	12	Pgain	Proportional gain in the PI-parts of the current controller. (256 = 1)
2070h	13	Igain	Integral gain in the PI-parts of the current controller. (256 = 1)
2070h	15	Lsigma	Total leakage inductance. Danaher Motion specific scaling. Used in the current controller.

Table 22. Current PI Controller with Decoupling and U_x Reference limitation - Parameters.

The [Table 23](#) describes the object indices of the variables (read only) within the Current Control that are accessible via CANopen.

Index	Sub-Index	Name	Description
2070h	1	Iq	Measured instantaneous torque current in deciA. Iq is sampled every 0.250 ms (4 kHz).
2070h	3	Id	Measured instantaneous magnetization in deciA . Id is sampled every 0.250 ms (4 kHz)
2070h	5	Uq Reference	Reference of the PWM generated motor voltage in the q-direction. Output from the current controller. $16384 = U_{dc}/\sqrt{2}$ VRMS (hsp) where $U_{dc} = 36, 48$ or 80 V
2070h	6	Ud Reference	Reference of the PWM generated motor voltage in the d-direction. Output from the current controller. $16384 = U_{dc}/\sqrt{2}$ VRMS (hsp) where $U_{dc} = 36, 48$ or 80 V
2070h	9	Magnetization Current	Commanded magnetization current in ARMS. Updated every 20 ms (50 Hz). The same as IdRef.
2070h	16	Torque Current	Commanded torque current in ARMS. Updated every 2 ms (500 Hz) from speed control. The same as IqRef.

Table 23. Current Control - Variables

6.11 TUNING OF CURRENT CONTROL

In order to tune the Current Control some motor data are required, namely the

- Stator and rotor leakage inductance ($L_{s\lambda}$ and $L_{r\lambda}$)
- Stator and rotor resistance @ 100 °C (R_s and R_r)

Normally these values are supported by Danaher Motion and the default Current Control parameters can be used (Table 22). However, from the impedance data of the motor the Pgain, Igain and Lsigma can be computed (checked) as follows.

The Pgain and Igain in the current PI controller can be calculated as:

$$P_{\text{gain}} = \frac{2 \cdot \pi \cdot f_c \cdot (L_{s\lambda} + L_{r\lambda})}{\frac{U_{\text{dc}}/\sqrt{3}}{I_{\text{base}} \cdot 4}} \cdot 256$$

$$I_{\text{gain}} = \frac{2 \cdot \pi \cdot f_c \cdot (R_s + R_r)}{\frac{U_{\text{dc}}/\sqrt{3}}{I_{\text{base}} \cdot 4}} \cdot \frac{1}{f_s} \cdot 256 \cdot 3$$

where:

- f_c = Current control bandwidth (200 Hz)
- f_s = Sampling (execution) frequency of the current control (4000 Hz)
- $L_{s\lambda}, L_{r\lambda}$ = Stator and rotor leakage inductance
- R_s, R_r = Stator and rotor resistance @ 100 °C
- U_{dc} = 24, 36, 48 or 80 V (corresponds to $16384 \cdot \sqrt{3}$ DSP units)
- I_{base} = 410 A (corresponds to 4096 DSP units)

The factor 3 in the computation of the Igain is introduced in order to improve the performance of the current control when the back emf inside the motor changes quickly. That happens when the derivative of the motor speed is high since the back emf is proportional to the motor speed.

The value of the decoupling factor Lsigma is calculated as

$$L_{\text{sigma}} = \frac{2 \cdot \pi \cdot f_{\text{base}} \cdot (L_{s\lambda} + L_{r\lambda})}{\frac{U_{\text{dc}}/\sqrt{3}}{I_{\text{base}} \cdot 4}} \cdot 4096$$

where $f_{\text{base}} = 50$ Hz

6.12 SPWM-SYM

6.12.1 BASICS

The principle of SPWM-sym (Sinusoidal Pulse Width Modulation with summarization) is shown in Figure 29.

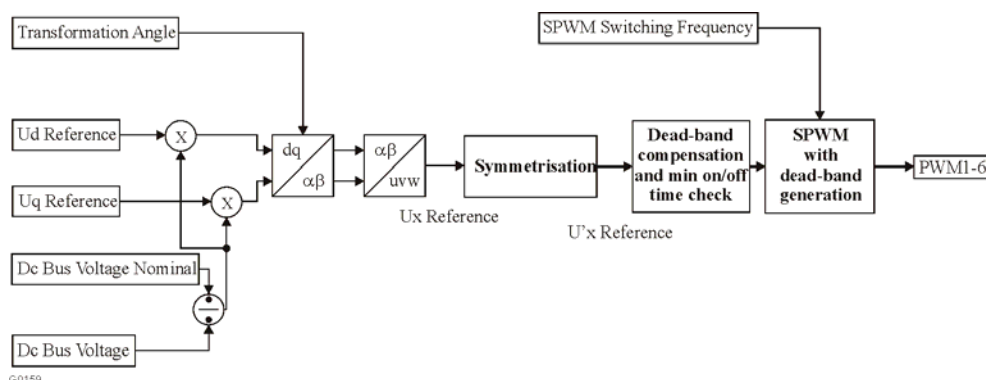


Figure 29. Simplified scheme of SPWM-sym.

The reference voltages, Ud Reference and Uq Reference, computed by the Current Control are first normalised with the ratio between the nominal DC bus voltage (36, 48 or 80 V) and the measured DC bus voltage. The voltages are then transformed to three phase quantities by the use of the transformation angle. The three phase reference voltages (Uu Reference, Uv Reference and Uw Reference) are symmetries according to Figure 30 before the dead-band compensation and the minimum on/off time check is done. The dead-band compensation is necessary in order to avoid disturbances in the motor currents. Especially third harmonics with relatively high amplitude will otherwise occur in the currents. The min on/off time check is done in order to protect the MOSFETs, i.e. a too short time between the turn-on and turn-off of a MOSFET may give permanent damage to the device. Finally the reference voltages are compared with a triangular reference wave and the intersection gives the switching instants. The frequency of the triangular carrier wave determines the PWM switching frequency. Nominally the switching frequency is equal to 8 kHz but with the parameter SPWM Switching Frequency it is possible to change it to 12 or 16 kHz even when the inverter is enabled (see Table 24). However, a higher switching frequency means higher losses in the inverter and thereby the rating of the ACS is decreased. The output from the DSP is the MOSFET gate pulses and the pulses are generated with the necessary dead-band between the turn-off and the turn-on of MOSFETs in each phase leg of the inverter.

Index	Sub-Index	Name	Description
2070h	19	SPWM Switching Frequency	8, 12 or 16 kHz.

Table 24. Parameter SPWM Switching Frequency in the SPWM-sym block.

The symmetrisation of the reference voltages is shown in Figure 30. With the symmetrisation it is possible to improve the utilization of the SPWM method, i.e. the range of the linear relationship between the reference voltages and the realized line-to-line voltages is extended compared to traditional SPWM. The symmetrisation method is comparable to the method where a third harmonic is added. However, symmetrisation is to prefer in a digital implementation since the harmonic content as well as the generated voltage time area is optimized during each PWM switching period.

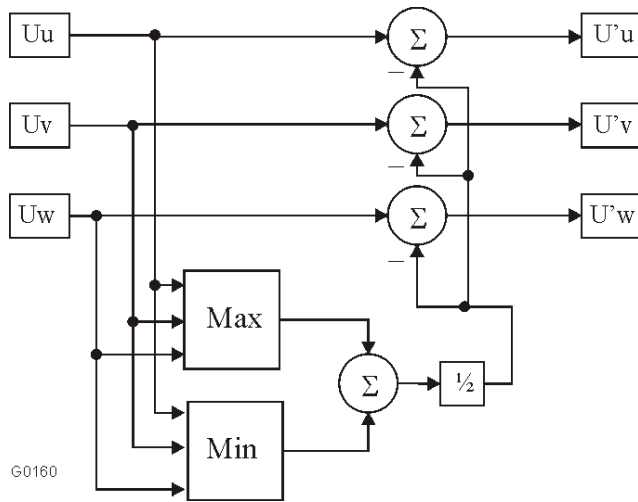


Figure 30. Symmetrisation of the reference voltages.

The maximum line-to-line voltage that can be generated with SPWM-sym without over modulation is $U_{\text{line-to-line}} = U_{\text{dc}}/\sqrt{2} \approx 0.707 \cdot U_{\text{dc}}$. Compared to traditional SPWM ($U_{\text{line-to-line}} = U_{\text{dc}}/2/\sqrt{2} \cdot \sqrt{3} \approx 0.612 \cdot U_{\text{dc}}$) the voltage is 15.4% higher but compared to square-wave modulation ($U_{\text{line-to-line}} = \sqrt{2}/\pi \cdot U_{\text{dc}} \cdot \sqrt{3} \approx 0.80 \cdot U_{\text{dc}}$) it is 9.3% lower. However the SPWM-sym block utilizes over modulation so the maximum voltage that is possible to generate is close to that of square-wave modulation.

Over modulation will occur above the base speed since the motor voltage then is high. The result of over modulation is that there will be less switching in the inverter since the reference voltages are above the triangular carrier wave during a number of PWM switching periods, i.e. the MOSFETs are mainly switching during the zero crossings of the reference voltages. The use of over modulation will increase the harmonic content in the motor currents mainly by adding 5th and 7th harmonics. This will increase the harmonic losses in the motor. However, since a higher voltage can be generated, the total losses will be lower than if no over modulation was used. It is because a lower fundamental current is required for a certain torque and it is the $R \cdot I^2$ losses in the motor caused by the fundamental part of the current that dominates compared to the increased harmonic losses.

An example of the resulting currents at no over modulation and over modulation can be seen in [Figure 31](#). The measurements are from a no load situation which means that there is only magnetization current. Therefore the harmonics at over modulation are rather high compared to the fundamental current.

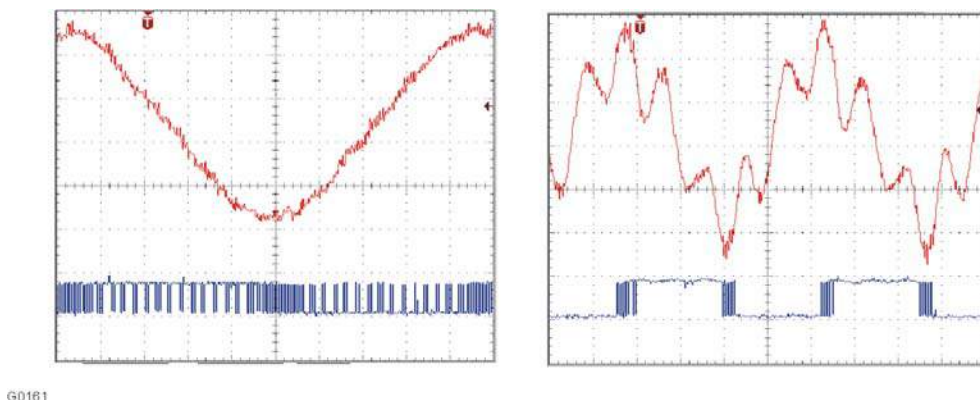


Figure 31. Examples of motor phase current (red) and voltage between phase and B- (blue) at
 - low speed and no over modulation (left figure)
 - high speed and over modulation (right figure)

6.13 OPEN DRAIN OUTPUT CONTROL

Two open drain outputs are available in K1 (Pin 2 and Pin 10). Each output can be either in Main Contactor mode or General Output mode and the mode is controlled with the parameter Open Drain Output 1 Mode and Open Drain Output 2 Mode.

In Main Contactor mode, the output is enabled when the ACS is switched on (bit 1 in the Status Word). In General Output mode, the output is controlled through the bit 6 (Open drain output 1 on) and bit 7 (Open drain output 2 on) in the Command Word. The Open Drain Outputs are voltage controlled in both modes and the voltage is defined as the voltage between B+ and Pin 2 in K1. In order to realize the commanded voltage PWM is used. The switching frequency is by default equal to 1 kHz but can be chosen also as 2, 4, 8 or 16 kHz.

The Open Drain Output voltage is implemented as shown in Figure 32. The Output can be set for a Pull Voltage when the output is enabled and a Hold Voltage that follows upon the Pull Voltage. The control of the function runs with 500 Hz, which means that the smallest Pull Time is 2 ms. If any time is set to zero that part of the output is removed. For example if the Pull Time is set to zero, no Pull Voltage will be generated.

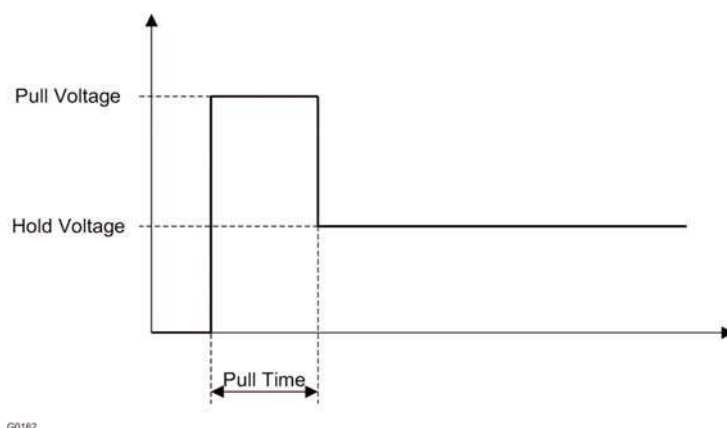


Figure 32. Open drain output functionality.

In order to generate an Open Drain Output voltage that is equal to the Dc Bus Voltage, the Pull Time is set to zero and the Hold Voltage is set to a voltage that always is above the Dc Bus Voltage (for example, 10000 centiV in a 48 V system).

6.13.1 PARAMETERS

The parameters and variables for the Open Drain Output Control are summarized in the following table.

Index	Sub-Index	Name	Description
2020h	2	Open Drain Output 1 Mode	Pin 2 in K1. 1 = Main contactor 2 = General output
2020h	3	Open Drain Output 2 Mode	Pin 10 in K1. 1 = Main contactor 2 = General output
2060h	2	Open Drain Output 1 : Pull Time	During this time in ms the Pull Voltage is generated.
2060h	3	Open Drain Output 1 : Pull Voltage	Initial voltage in centiV between B+ and output (Pin 2 in K1) when output is enabled.
2060h	4	Open Drain Output 1 : Hold Voltage	Voltage in centiV that follows upon the Pull Voltage.
2061h	2	Open Drain Output 2 : Pull Time	During this time in ms the Pull Voltage is generated.
2061h	3	Open Drain Output 2 : Pull Voltage	Initial voltage in centiV between B+ and output (Pin 10 in K1) when output is enabled.
2061h	4	Open Drain Output 2 : Hold Voltage	Voltage in centiV that follows upon the Pull Voltage.
2062h	2	Current	Total current in mA through the Open Darin Outputs.
2062	3	Switching Frequency	Open Drain Outputs Switching Frequency (1, 2, 4, 8 or 16 kHz)

Table 25. Open Drain Output Control – Parameters and Variables.

6.14 HOW THE AC SUPERDRIVE HANDLES PARAMETERS

6.14.1 GENERAL

Parameters are stored in EEPROM memory, which provides non-volatile storage with the capability to change parameter values. [Figure 33. Parameter Access and Flow.](#) shows the organization of AC SuperDrive memory and the paths over which parameter flow.

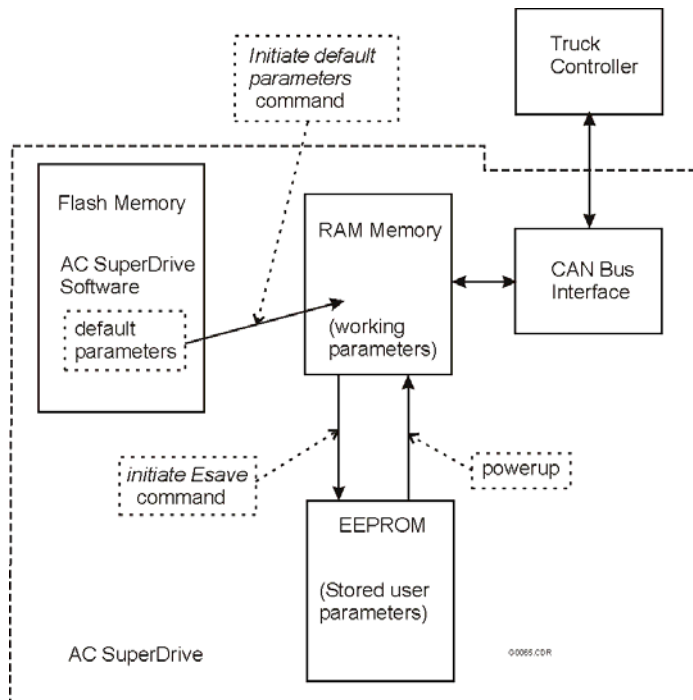


Figure 33. Parameter Access and Flow.

6.14.2 PARAMETER VERIFICATION AT STARTUP

Upon power up (when power is applied to the KEYSTART input) drive software copies parameter values from EEPROM memory into a segment of RAM memory reserved for parameters. The operating software then performs several checks to verify the validity of the parameter set in RAM. The parameters set is considered invalid whenever any of the following discrepancies are detected.

- ACS Id (from connector K1-8 & K1-9) \neq ACS Id (read from EEPROM)
- Application SW Build Time (read from Flash Memory) \neq Application SW Build Time (read from EEPROM)
- Parameter checksum error.

When an invalid set of parameters is detected, the AC SuperDrive operating software performs the following actions:

- Copies default parameters from flash memory into RAM.
- Updates ACS Id from connector K1.

- Updates Application SW Build Time stored with parameters.
- Computes checksum.
- Saves parameters to EEPROM.
- Sets Default parameters (Bit 15) in the Status Word.

The truck controller may then permit default parameters to be used or download different parameters to the SuperDrive.

During operation, all parameter read and write operations access the "working parameters" in RAM memory. The content of RAM memory is lost whenever power is removed from the KEYSTART input. The truck controller must take specific actions (see next section, Saving parameters) to permanently save parameter value changes.

6.14.3 SAVING PARAMETERS

In order to update the permanent set of parameter values in EEPROM memory, the truck controller must *Initiate Esave* by writing the value 65766173h to CANopen object Store All Parameters (1010h:1). Saving parameters shall be performed with the vehicle at standstill.

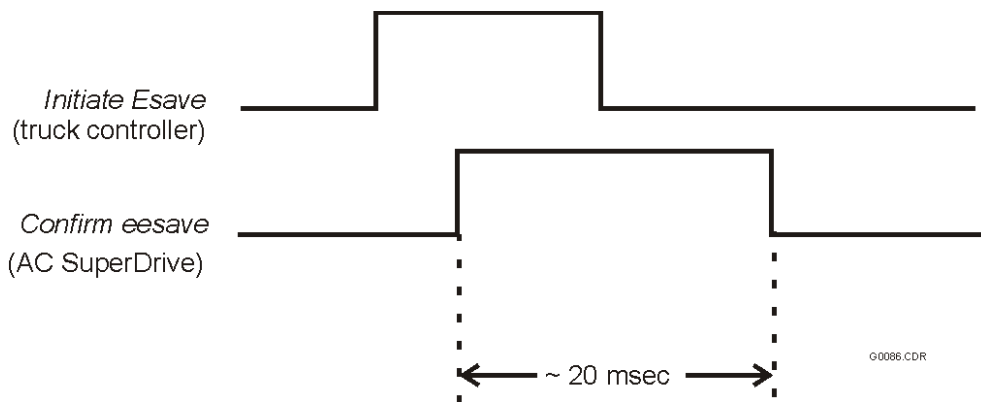


Figure 34. Procedure for saving Parameters to Flash Memory.

6.14.4 DUPLICATING A CONFIGURATION

The fact that the operating characteristics of an AC SuperDrive are determined by a set of numbers (parameters) combined with the digital nature of the drive assures that two AC SuperDrives identically configured behave identically in a given application.

In a production environment any of the following methods may be employed to configure AC SuperDrives:

- The user-specified configuration can include as default parameters by Danaher Motion during the manufacturing process.
- The user may download the configuration to the drive as a step in his vehicle assembly process.
This requires a PC with CAN Bus interface and software to perform the procedure.
- The user may download the configuration to the drive from the truck controller.

6.14.5 REVERTING TO DEFAULT PARAMETERS

The user may revert to default parameters (stored in flash memory along with the AC SuperDrive software) using a procedure similar to saving parameters, i.e. by writing the value 64616F6Ch to CANopen object Restore All Default Parameters (1011h:1). [Figure 35](#) illustrates the procedure.

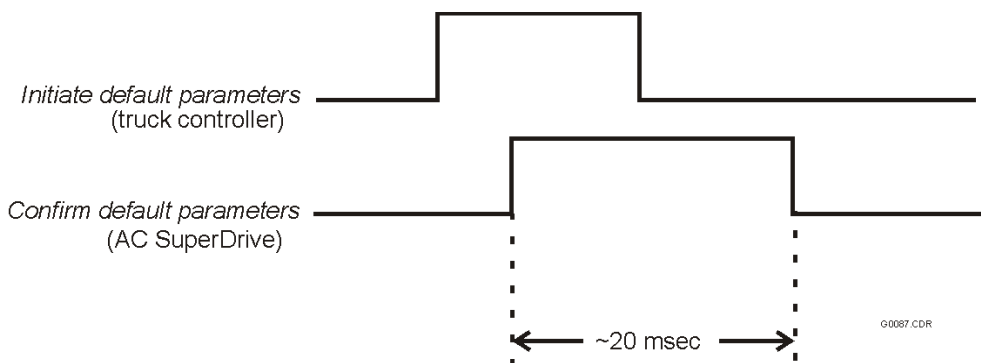


Figure 35. Procedure for reverting to default parameters.

7 TROUBLESHOOTING GUIDE

7.1 GENERAL

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

i The Symptom, Emergency Error codes Errors and Warning bitfield codes and related troubleshooting charts presented in this section are utilizing the CANopen communications protocol. For further information on the CANopen object, see Object Dictionary documentation.

7.2 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.

7.3 ERRORS

The AC SuperDrive 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 SuperDrive.

When an error is detected

- The AC SuperDrive 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 is saved to the Error Log.
- The Time is saved to the Operation Times.
- The LED indicator starts to flash fast (10Hz).

7.4 WARNINGS

Less serious problems, which permit continued AC SuperDrive operation, often at reduced capacity, produce warnings. The AC SuperDrive's internal warning status is updated to reflect the code(s) for existing warning conditions. Operating with active warning conditions does affect the AC SuperDrive status LED indicator, which changes from steady on to slow (1Hz) flashing. When

the root cause of a warning is removed, the AC SuperDrive 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).

7.5 STATUS INDICATOR

The LED status indicator, shown in [Figure 36](#), provides a visual identification of the AC SuperDrives operating status.

STATUS	DESCRIPTION
Steady green light.	The controller is ok.
Fast flashing light. (10Hz)	An error is reported to the controller. When an error occurs, the AC SuperDrive immediately stops motion then shuts down the drive's power output to the motor.
Slow flashing light. (1Hz)	A warning is active.

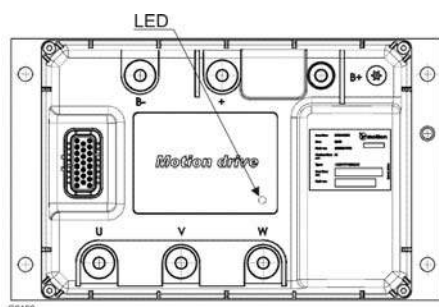


Figure 36. The LED status indicator placement.

7.6 USING THE TROUBLESHOOTING GUIDE

CAUTION

♦ Do not manually operate main contactor or override system control of main contactor without first isolating AC SuperDrive B+ (or +) terminal from main contactor output.

This troubleshooting guide is organized by visual symptoms and error/warning codes produced by the AC SuperDrive. 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 26](#), error code in [Table 27](#) and warning code in [Table 28](#), and then refer to the troubleshooting chart on the referenced page. After performing a corrective action, restart the AC SuperDrive and verify that the error/warning

Locate the observed symptom(s) in [Table 26](#), error code in [Table 27](#) and warning code in [Table 28](#), and then refer to the troubleshooting chart on the referenced page. After performing a corrective action, restart the AC SuperDrive 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.

Symptom code	See page
Main contactor doesn't close within 10 seconds after switching on key switch.	73
Fuse to Power Stage is blown.	74
AC SuperDrive Status indicator is blinking or off.	75
Motor runs only at low speed, with a ticking sound.	76

Table 26. Symptom versus Troubleshooting Chart.

Emergency Error code	Extended Errors bit field code index 3010h,2	Error	See page
0x2310	0x2000	AC Current - Over current.	83
0x2340	0x0001	AC Current – Short circuit.	83
0x3120	0x0010	No Charging DC Bus.	85
0x3211	0x0004	DC Bus high – software detected.	84
0x3212	0x0008	DC Bus high – hardware detected.	84
0x3221	0x0002	DC Bus low.	85
0x4210	0x0020	Motor temperature high.	78
0x4310	0x0040 / 0x0080	Heatsink Over temperature.	80
0x5111	0x0400	15 V Supply low voltage	90
0x5113	0x0800	15 V Supply low or high voltage	90
0x5210	0x0200	Current sensors offset calibration error	90
0x5410	0x1000	Open Drain Output Current High	NA
0x8100	0x0100	CAN Time Out.	86

Table 27. Error versus Troubleshooting Chart.

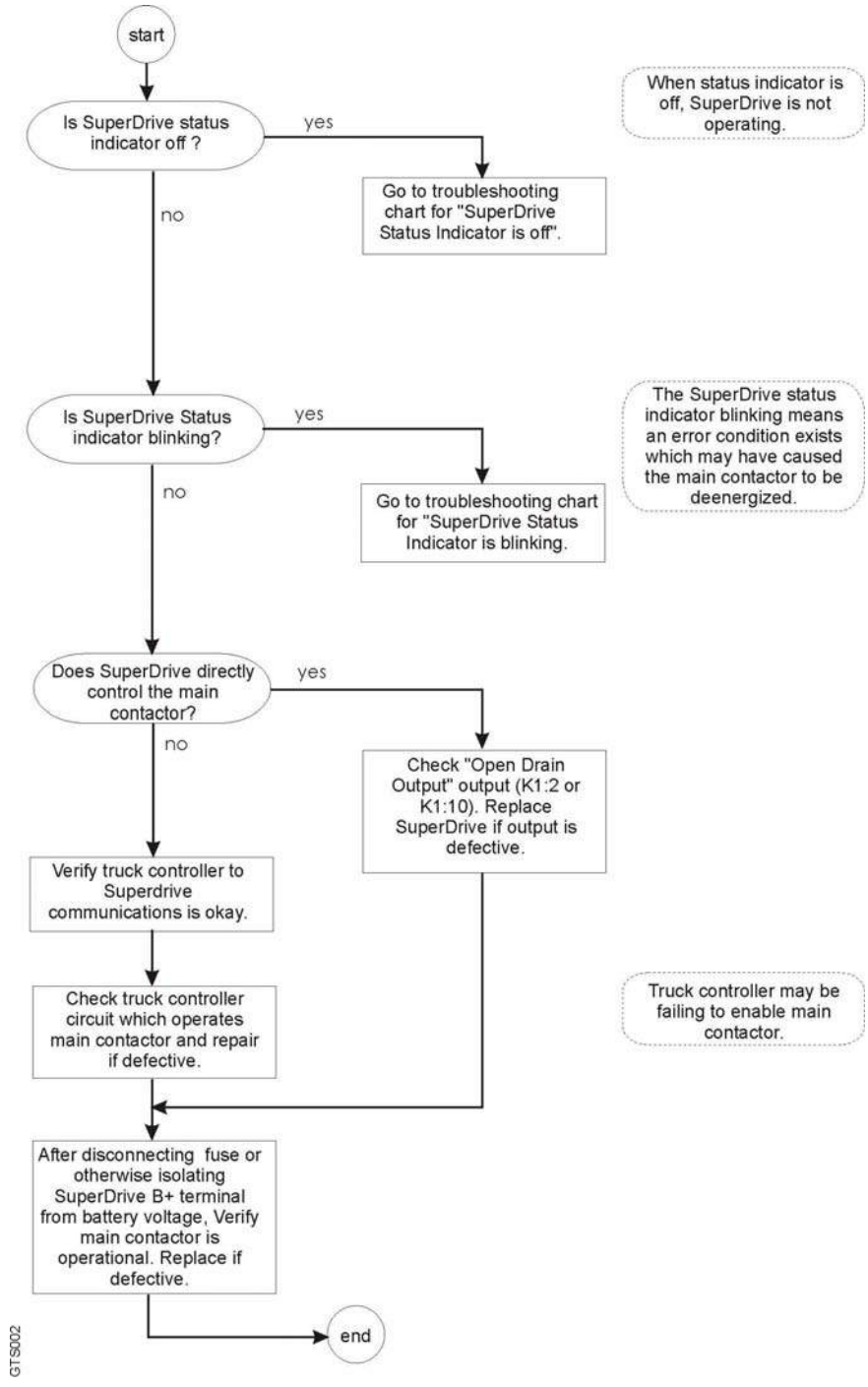
Extended Warning bit field code Index 3010h, 1	Warning	See page
0x0001	Low voltage	NA
0x0002	High voltage	NA
0x0004	DC Bus calibration	NA
0x0008	Motor temperature low, <-50°C	88
0x0010	Motor temperature high>145°C	78
0x0020	Motor temperature sensor not connected/short circuit	89
0x0040	Heat sink temperature 1 low<-20°C	88
0x0080	Heat sink temperature 1 high >85°C	80
0x0100	Heat sink temperature sensor 1 not connected/short circuit	87
0x0200	Heat sink temperature 2 low<-20°C	88
0x0400	Heat sink temperature 2 high >85°C	80
0x0800	Heat sink temperature sensor 2 not connected/short circuit	87
0x1000	Default parameters	91
0x2000	Power reduction due to temperature (motor or heatsink).	78, 80, 88
0x4000	Speed feedback sensor not connected/short circuit	77
0x8000	Current Measurement Calibration.	NA
0x40000	Open Drain Output Current High Warning	NA
0x80000	Open Drain Output Current High Error	NA

Table 28. Warning versus Troubleshooting Chart.

7.7 TROUBLESHOOTING CHART

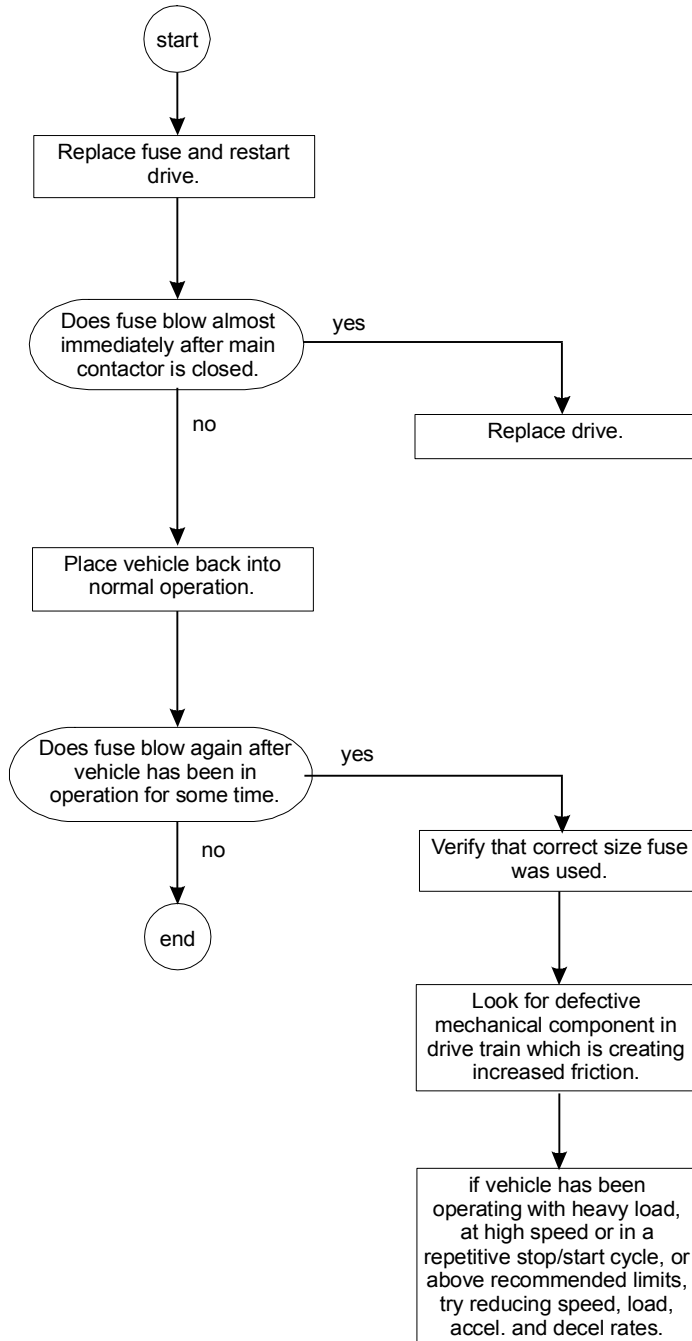
7.7.1 MAIN CONTACTOR DOESN'T CLOSE

Symptom



7.7.2 FUSE TO POWER STAGE IS BLOWN

Symptom



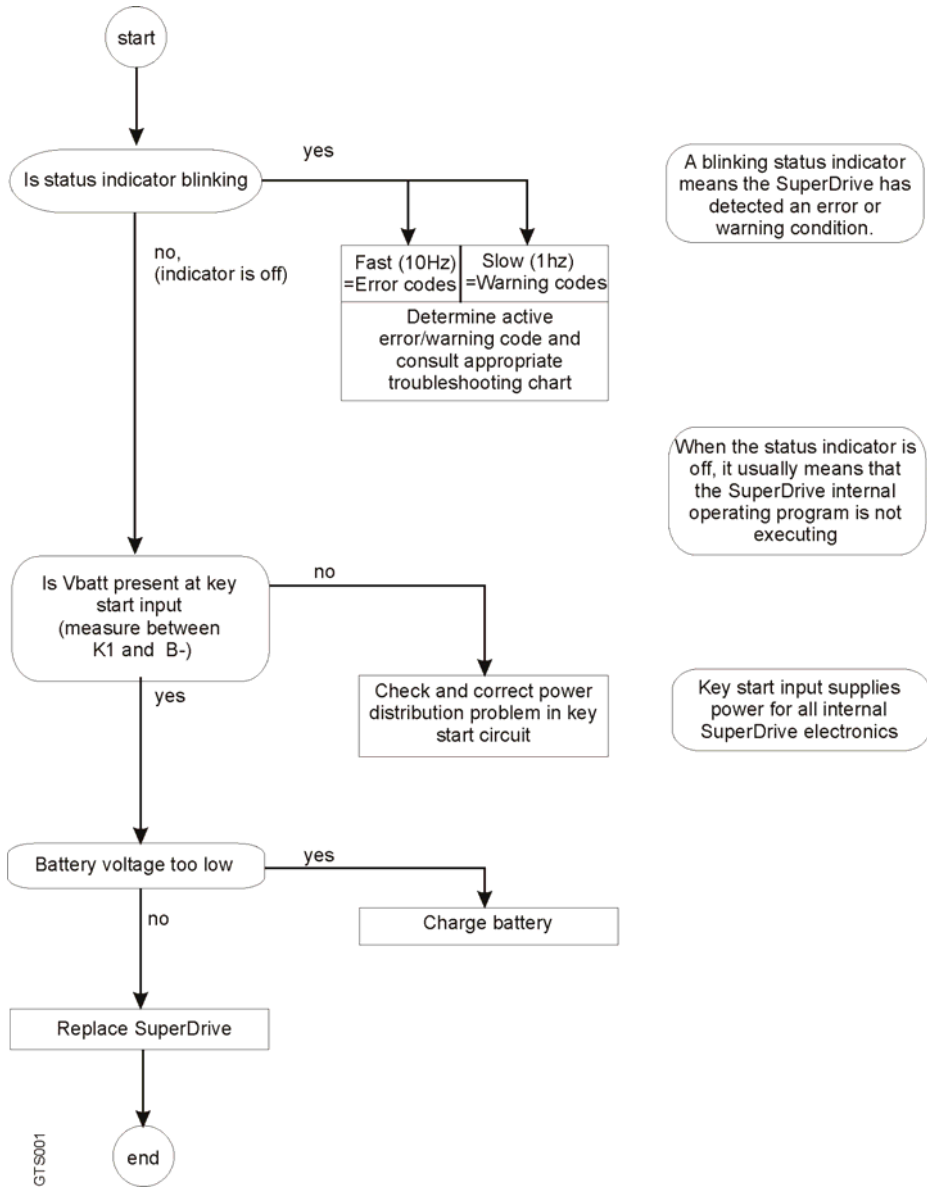
The most likely reasons for a blown fuse are a short circuit in the drive power stage or the average current drawn by the drive exceeds the fuse rating.

Increased friction, heavier load, high speed and rapid start/stop all increase average current drawn by the drive. Vehicle may have been operating at power levels beyond it's operating limit.

GTS012.CDR

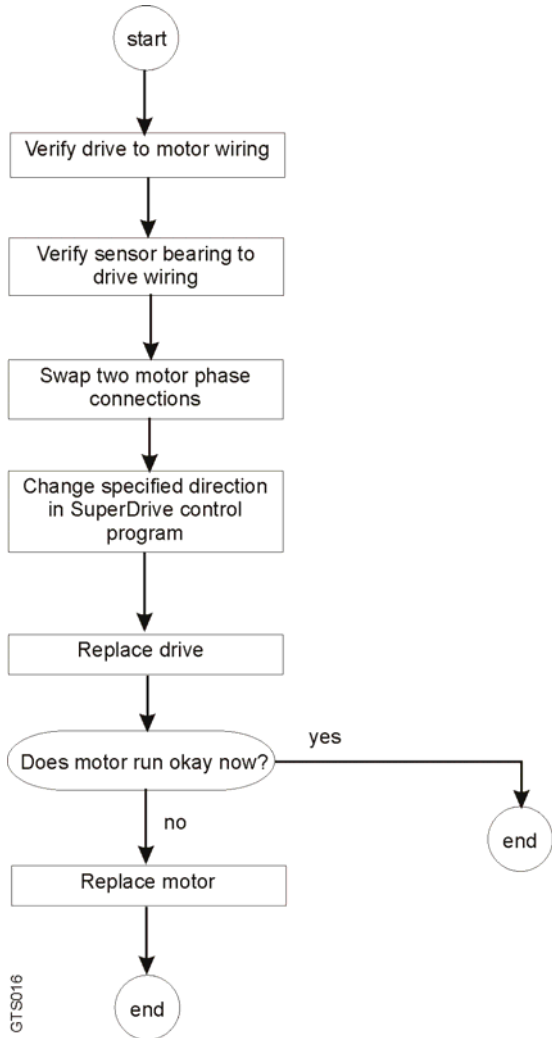
7.7.3 AC SUPERDRIVE STATUS INDICATOR IS FLASHING OR OFF

Symptom



7.7.4 MOTOR RUNS ONLY AT LOW SPEED

Symptom



If motor, drive or wiring was replaced, look for motor to drive or sensor bearing to drive wiring error. If not, look for a loose or broken connection.

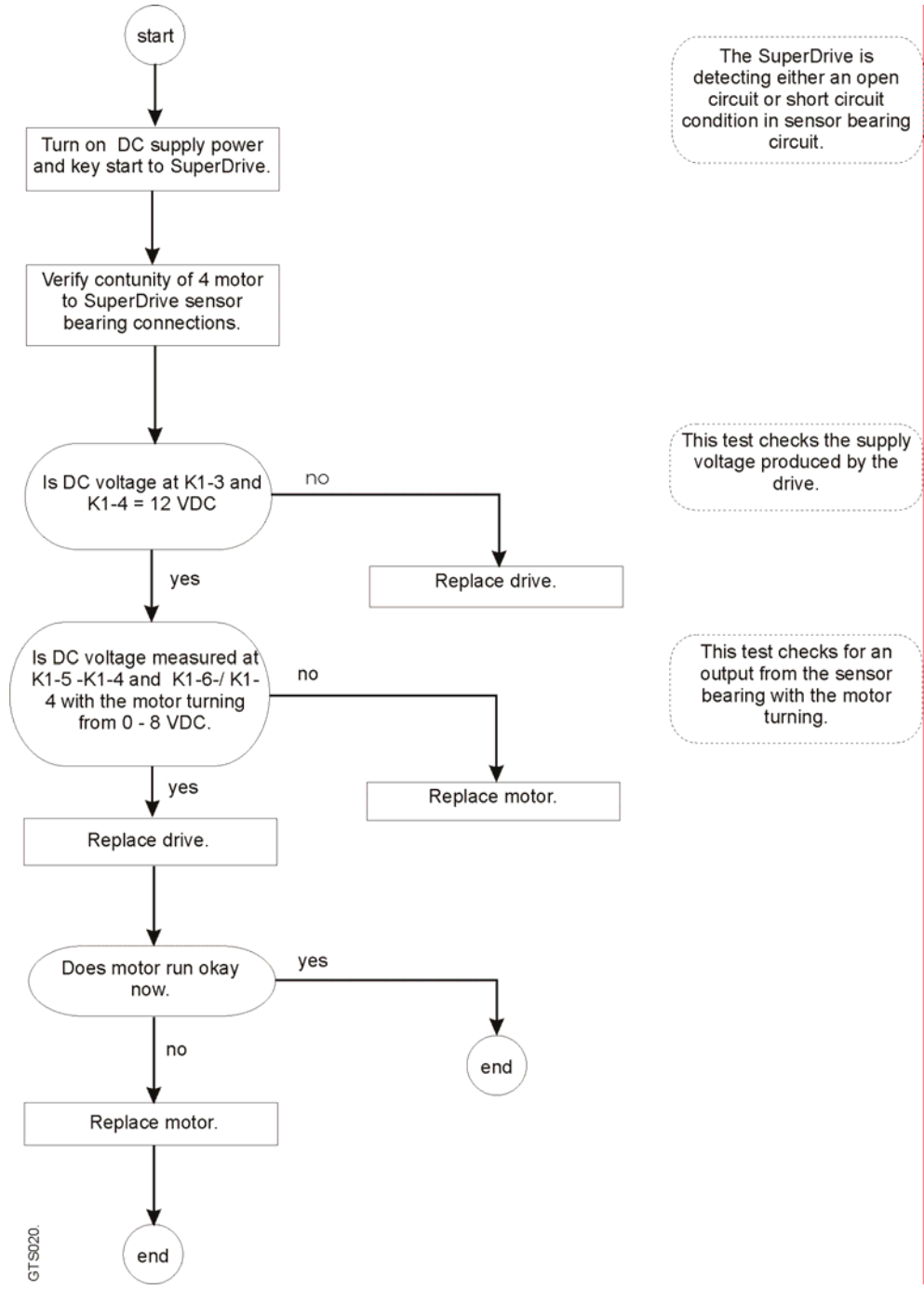
Motor phase windings may be labelled incorrectly.

Contact an InMotion Applications Center for assistance in making this control program modification.

GTS016

7.7.5 SPEED FEEDBACK SENSOR NOT CONNECTED

Warning Code	0x4000
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7.7.6 MOTOR TEMPERATURE ERROR

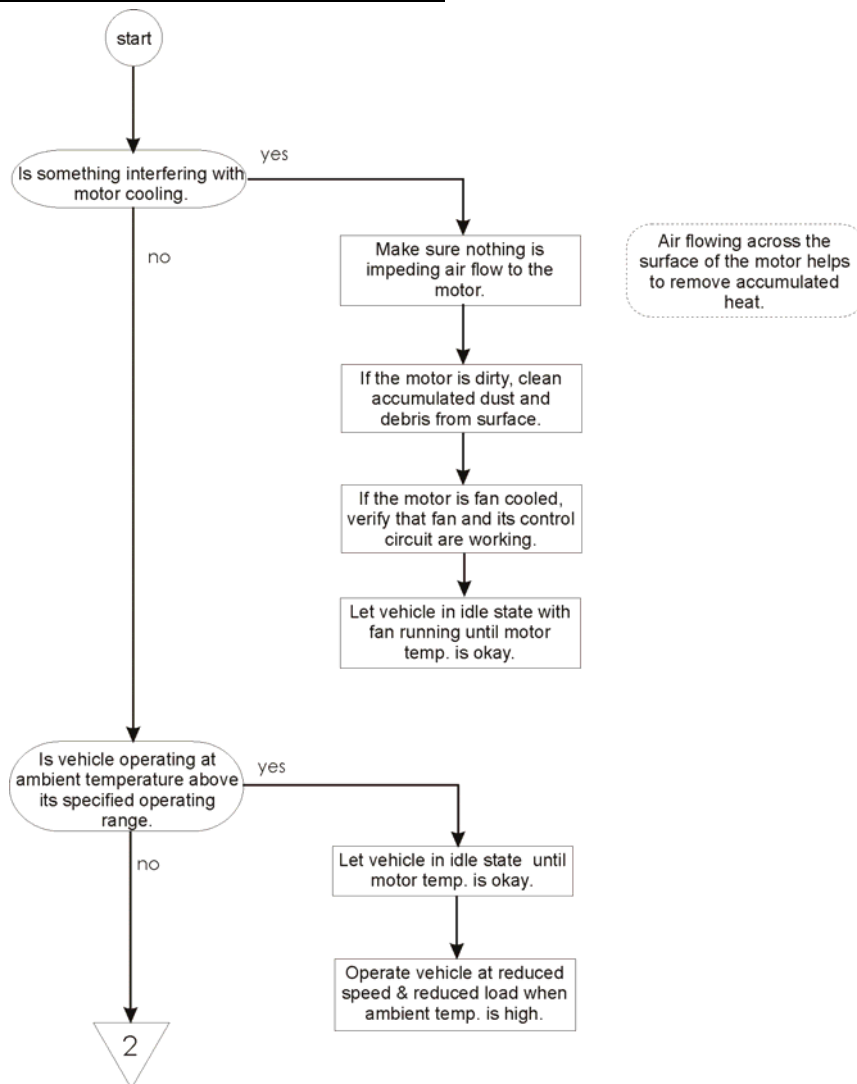
Error Code	0x4210
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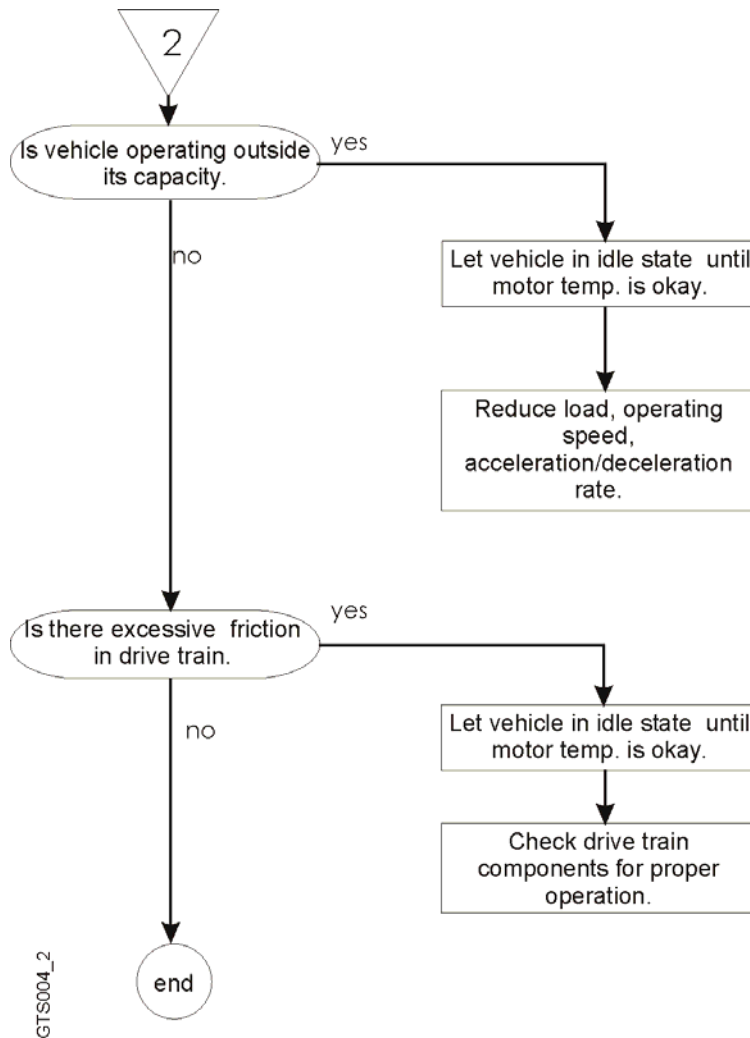
POWER LIMITED DUE TO OVER TEMPERATURE

Warning Code	0x2000
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POWER REDUCTION DUE TO MOTOR OVER TEMPERATURE

Warning Code	0x0010
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7.7.7 HEATSINK OVER TEMPERATURE ERROR

Error Code	0x4310
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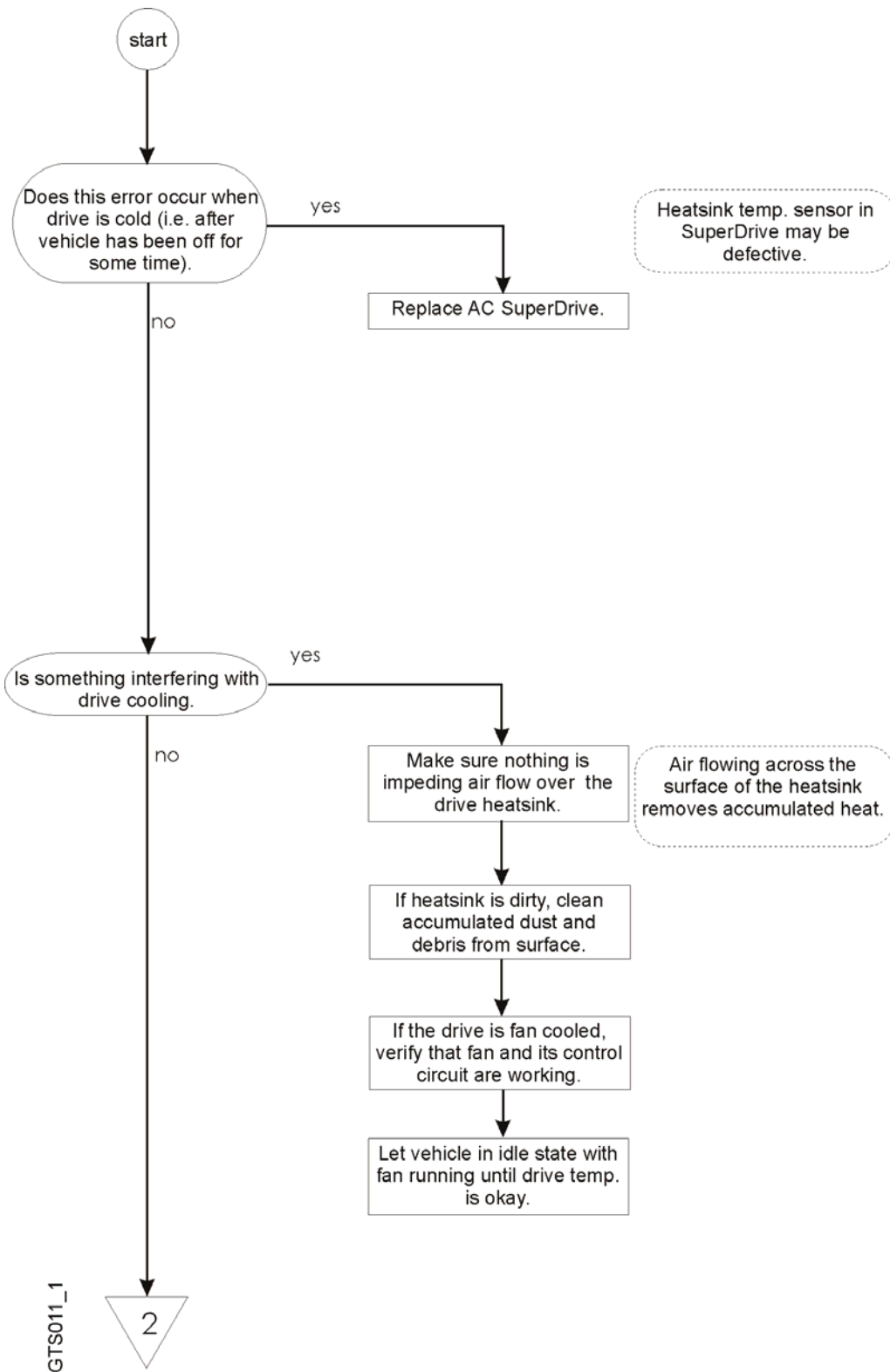
***POWER LIMITED DUE TO HEATSINK OVER TEMPERATURE
1, 2 > 85 °C***

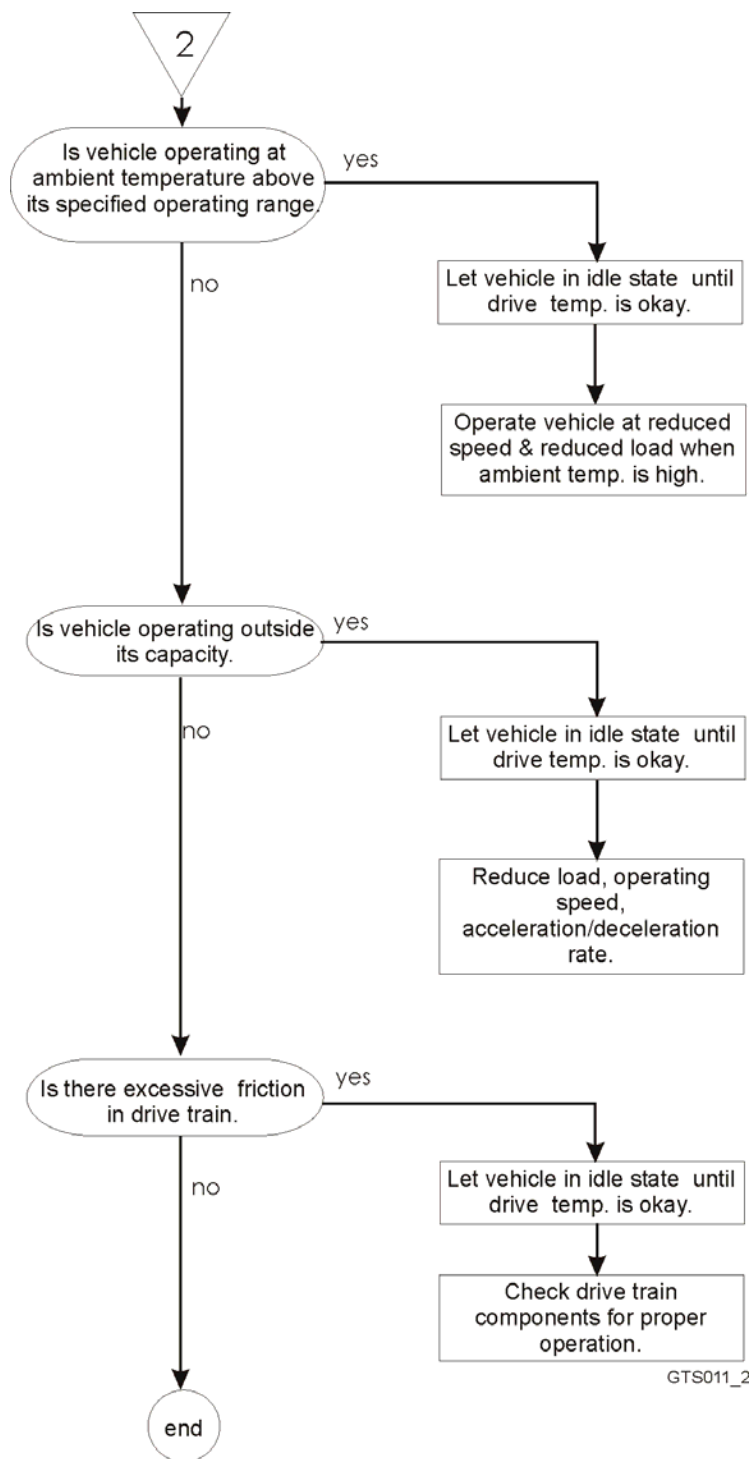
Warning Code	0x0080	1
	0x0400	2

POWER REDUCTION DUE TO TEMPERATURE

Warning Code	0x2000
--------------	--------

See next page



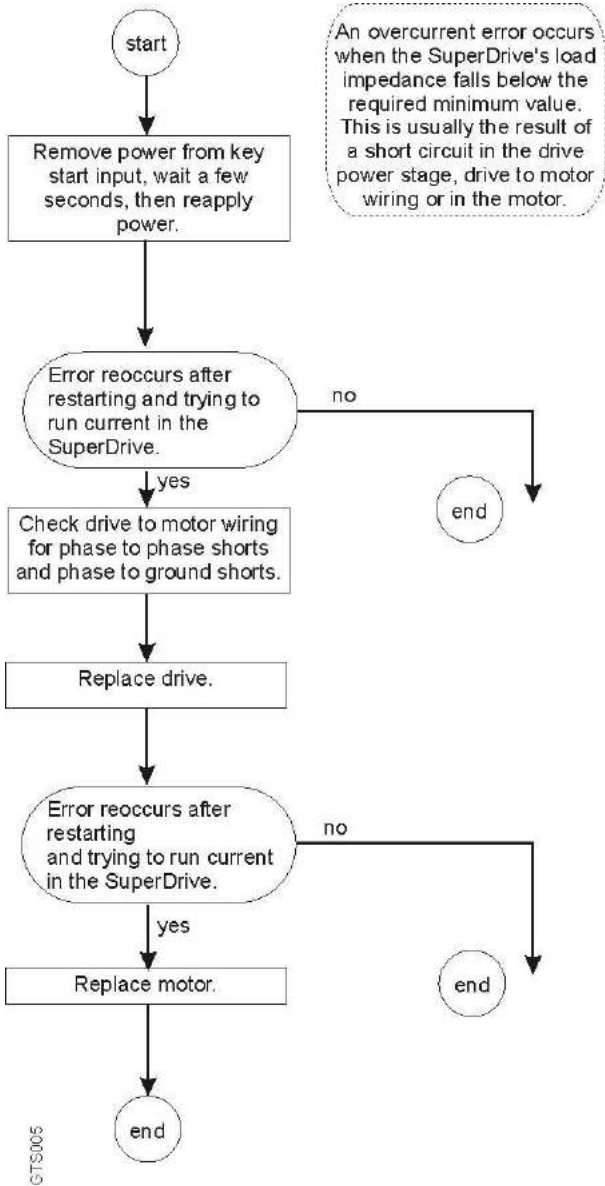


7.7.8 AC CURRENT OVER CURRENT

Error Code	0x2310
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AC CURRENT SHORT CIRCUIT

Error Code	0x2340
------------	--------

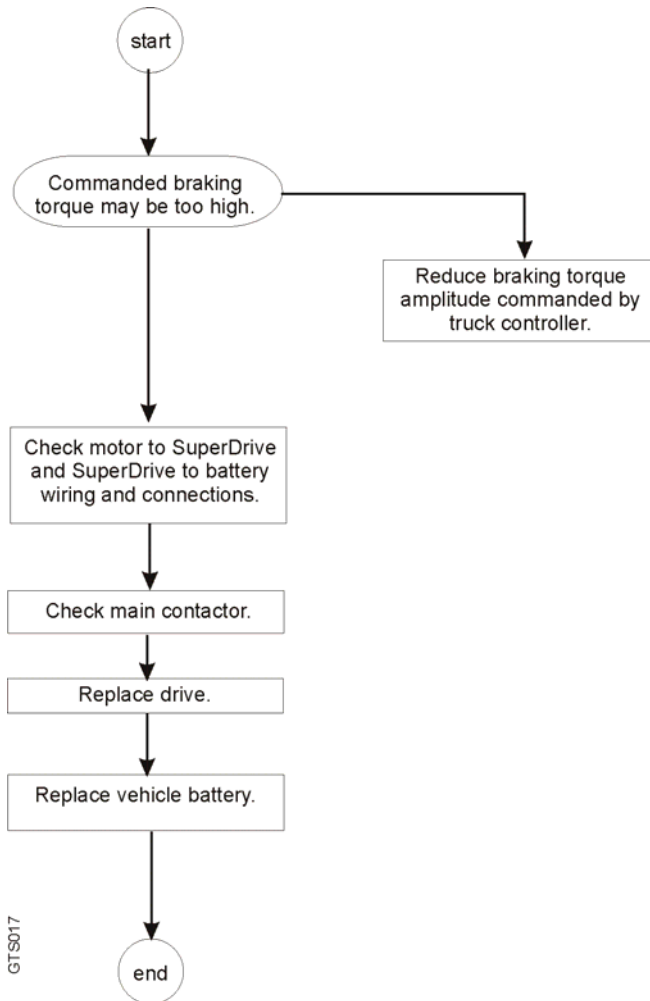


7.7.9 DC BUS HIGH - HARDWARE DETECTED

Error Code	0x3212
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DC BUS HIGH - SOFTWARE DETECTED

Error Code	0x3211
------------	--------



GTS017

This error occurs when the SuperDrive detects that Vbatt is too high for safe operation of the drive. This condition is usually the result of too much regenerated energy returned to the battery or high resistance between SuperDrive and battery. Vbatt (measured between + & B- terminals) for AC SuperDrive models must not exceed approximately:

ACS Model	max Supply
ACS 36	50 VDC
ACS 48	65 VDC
ACS 80	110 VDC

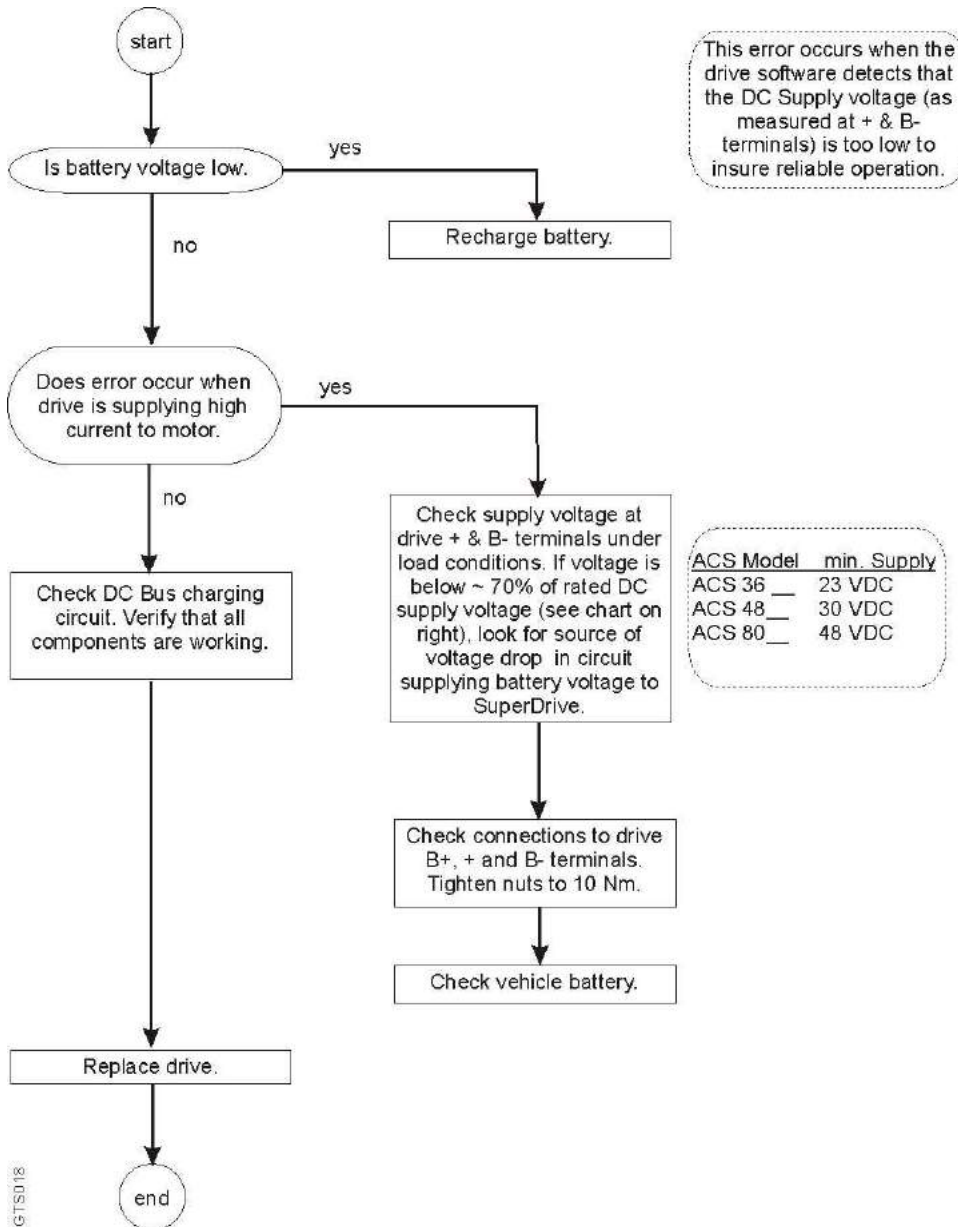
Supply voltage measurement by SuperDrive may be defective.

7.7.10 DC BUS LOW

Error Code	0x3221
------------	--------

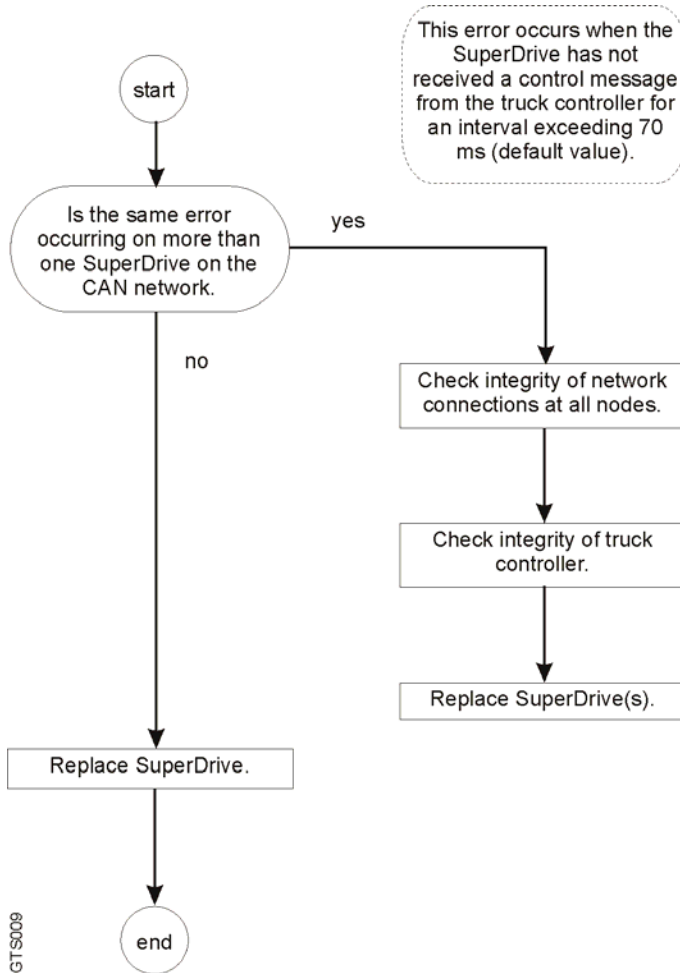
NO CHARGING DC BUS

Error Code	0x3120
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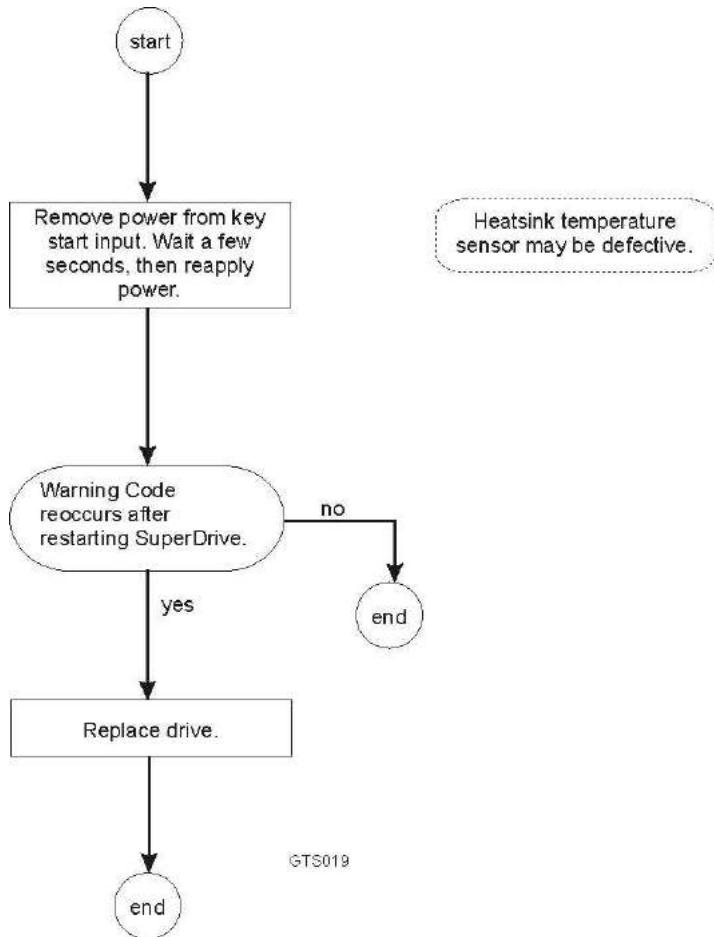
7.7.11 CAN –TIME OUT

Error Code	0x8100
------------	--------



7.7.12 HEATSINK TEMPERATURE SENSOR 1,2 – OPEN CIRCUIT/SHORT CIRCUIT

Warning Code	0x0100	1
	0x0800	2



7.7.13 MOTOR - TEMP < -50 °C

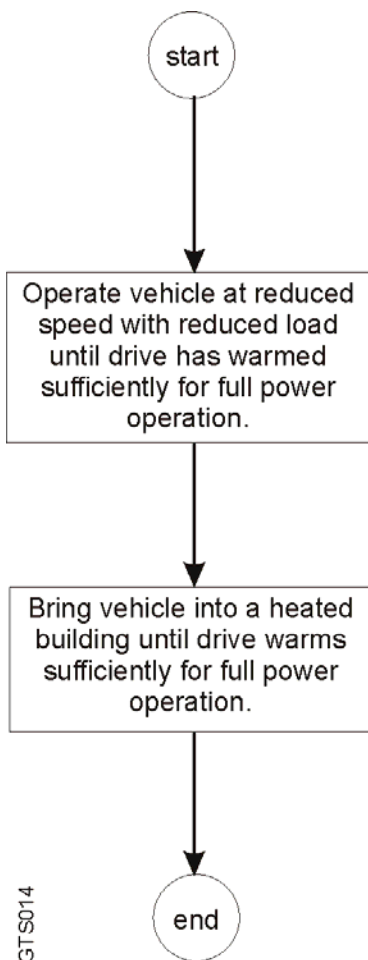
Warning Code	0x0008
--------------	--------

HEATSINK MOTOR- TEMP 1, 2 < -20 °C

Warning Code	0x0040	1
	0x0200	2

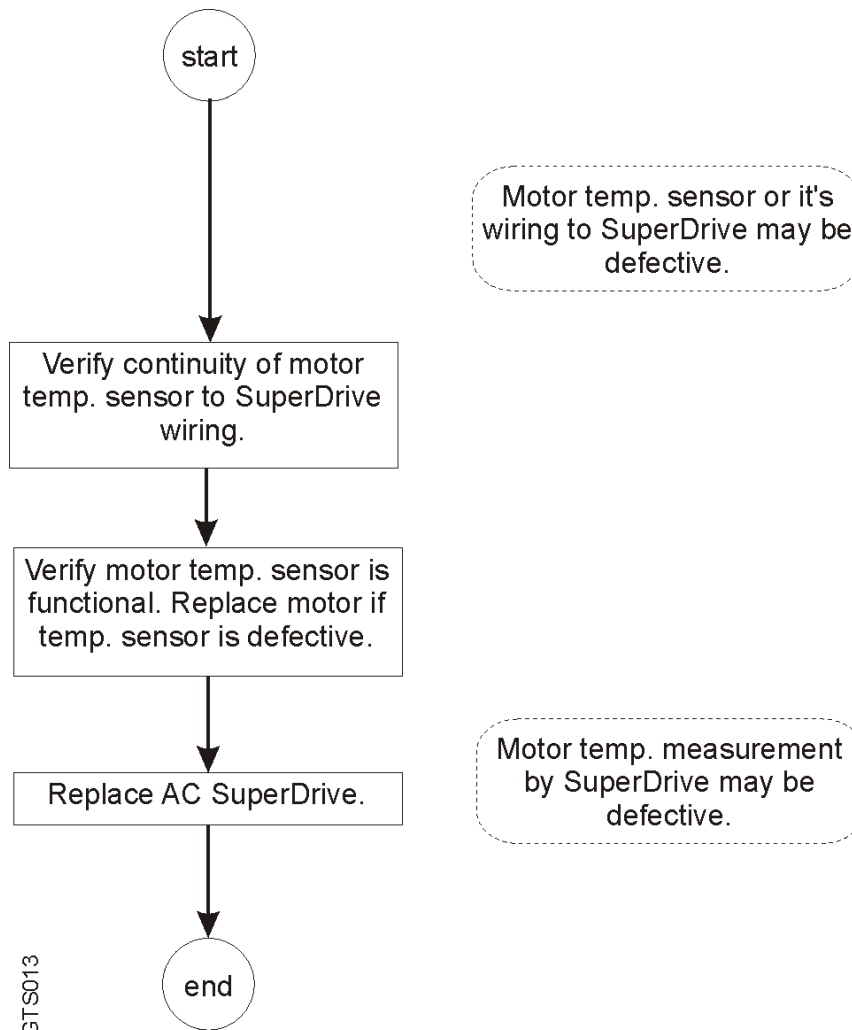
POWER REDUCTION

Warning Code	0x2000
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7.7.14 MOTOR TEMPERATURE SENSOR OPEN CIRCUIT/SHORT CIRCUIT

Warning Code	0x0020
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7.7.15 15 V SUPPLY LOW VOLTAGE

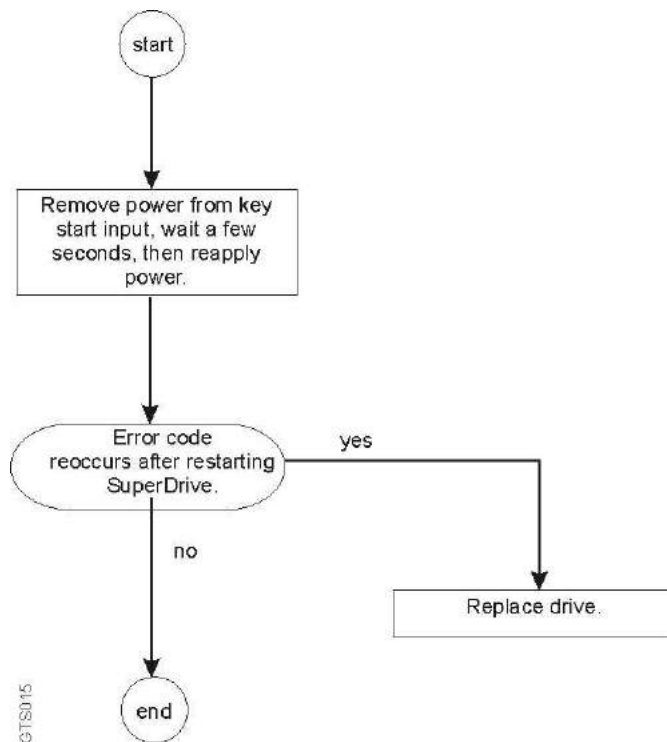
Error Code	0x5111
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15 V SUPPLY LOW OR HIGH VOLTAGE

Error Code	0x5113
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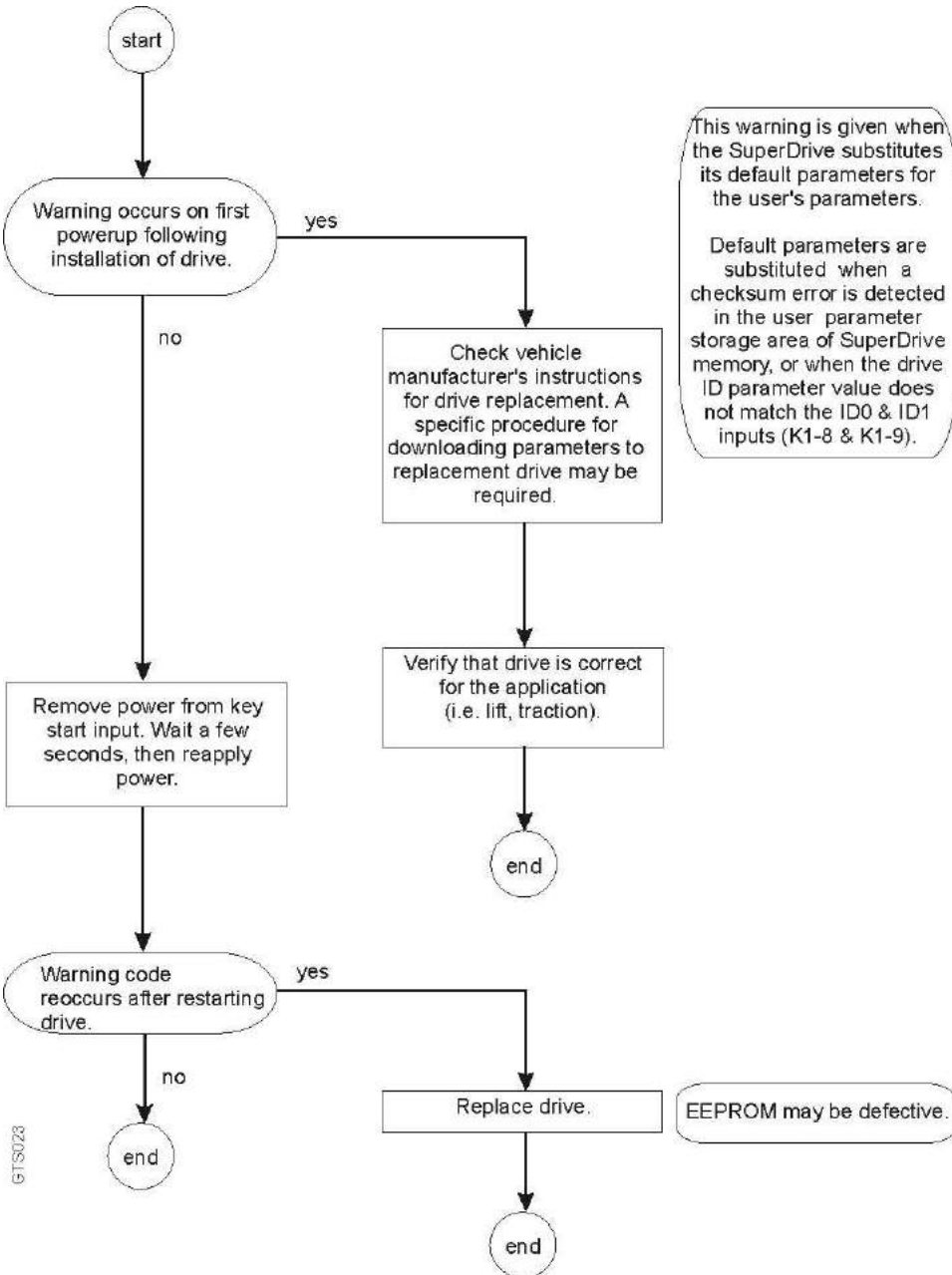
CURRENT CALIBRATION ERROR

Error Code	0x5210
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7.7.16 REVERTED TO DEFAULT PARAMETERS

Warning Code	0x1000
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8 AC SUPERDRIVE SPECIFICATIONS

8.1 GENERAL

MOTOR TYPE.	3-phase induction motor with squirrel cage rotor.
NO. OF QUADRANTS.	1,2,4 quadrant control.
BRAKING	Regenerative.
MODULATION.	PWM (Pulse Width Modulation).
SWITCHING FREQUENCY	8, 12 ^{optional} , 16 ^{optional} kHz.
OPERATING STATOR CURRENT FREQUENCY.	0-250 Hz.
CONTROL MODE.	Speed or torque control.

8.2 CURRENT AND POWER OUTPUT RATINGS

AC SuperDrive model ACS	Nominal DC supply voltage U _{dc} (note 3)	Driving current (2 min. rating) (see note 2) A _{rms}	Driving current (1 hour rating) (see note 1) A _{rms}	Power output (2 min. rating) (see note 2) kVA	Power output (1 hour rating) (see note 1) kVA
2410-450xxx	24	450	200	11.6	5.1
2415-675 xxx	24	675	300	17.4	7.7
3610-450 xxx	24/36	450	200	18.2	8.1
3615-675 xxx	24/36	675	300	27.3	12.1
3620-900 xxx	36	900	400	36.4	16.2
4810-350 xxx	48	350	150	19.3	8.3
4815-525 xxx	48	525	225	28.9	12.4
4820-700 xxx	48	700	300	38.6	16.5
4825-875 xxx	48	875	375	48.2	20.7
4825-1000 xxx	48	1000	400	55.1	22.0
8010-220 xxx	80	220	100	20.7	9.4
8015-330 xxx	80	330	150	31.1	14.1
8020-440 xxx	80	440	200	41.5	18.9
8025-550 xxx	80	550	220	51.9	23.6
xxx; F = Fins, C = Flat / Switching frequency 8 kHz					
Note 1:	Driving current (one hour rating) and power output (one hour rating) based cooling requirement for both heatsink version and air temperature of 40 °C, see Operating environment .				
Note 2:	Driving current (2 minute rating) and power output (2 minute rating) based on initial heatsink temperature of 25 °C, air temperature of 25 °C. and cooling requirement for both heatsink version, see Operating environment .				
Note 3:	U _{ac} out to motor is approx $\frac{U_{dc} - 3V}{\sqrt{2}}$				

8.3 DC SUPPLY VOLTAGE REQUIREMENT

AC SuperDrive model	Nominal DC Supply Voltage VDC	Operating range VDC	Instantaneous minimum (< 50 ms) VDC	Instantaneous maximum (<100 μ s) VDC
ACS24xx	24	16-32	10	36
ACS36xx	36	25 – 46	18	50.4
ACS48xx	48	34 – 62	24	67.2
ACS80xx	80	56 – 104	40	112

xx = 10, 15, 20, 25

8.4 ISOLATION

B- TERMINAL TO HEATSINK According to EN 1175-1. and UL 583
500-1200 VAC 1 MIN.

8.5 CAN COMMUNICATIONS INTERFACE

CAN PROTOCOL. CANopen.
PHYSICAL INTERFACE. ISO 11898.
BIT RATE 125, 250 and 500 kB/s

8.6 SAFETY SYSTEM

GENERAL.

- When error is detected, controller disables power outputs within 150 ms.
- CAN Communication watchdog time out 50 ms.
- Errors are reported via the CAN link.
- When controller is okay, LED indicator is steady green.
- When error condition(s) exist, LED is flashing fast (10Hz).
- When warning condition(s) exist, LED is flashing slow (1Hz).

OVERCURRENT. Power Conversion section disabled on over current condition

UNDERVOLTAGE. Power Conversion section disabled if + (battery voltage) input < lower limit of DC supply voltage operating range for unit (see page 94)

OVERVOLTAGE. Power Conversion section disabled if + (battery voltage) input > upper limit of DC supply voltage operating range for unit (see page 94).

THERMAL PROTECTION. Linear current rollback beginning at 85°C, down to 0 A 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 0 A at 165°C in motor.

8.7 OPERATING ENVIRONMENT

OPERATING TEMPERATURE -40°C to +55°C (-40°F to +131°F)
STORAGE TEMPERATURE -40°C to +70°C (-40°F to +158°F), ambient

	humidity of 95%.										
HUMIDITY	100% condensing according to IEC68-2-30, Db										
COOLING AC SUPERDRIVE WITH FINS.	6 m/s forced air cooling between fins required for one hour driving current ratings listed										
Cooling AC SuperDrive flat.	<table border="1"> <thead> <tr> <th>ACS Size</th> <th>Thermal resistance °C/W</th> </tr> </thead> <tbody> <tr> <td>xx10</td> <td>0.12</td> </tr> <tr> <td>xx15</td> <td>0.087</td> </tr> <tr> <td>xx20</td> <td>0.067</td> </tr> <tr> <td>xx25</td> <td>0.055</td> </tr> </tbody> </table>	ACS Size	Thermal resistance °C/W	xx10	0.12	xx15	0.087	xx20	0.067	xx25	0.055
ACS Size	Thermal resistance °C/W										
xx10	0.12										
xx15	0.087										
xx20	0.067										
xx25	0.055										

8.8 EMC

ELECTROMAGNETIC COMPATIBILITY	According to European standard EN12895, Industrial Trucks (radiated immunity, emission, ESD)
ELECTRICAL FAST TRANSIENT /BURST	EN61000-4-4 level 2

8.9 SAFETY AND TESTING STANDARDS COMPLIANCE

SAFETY, INDUSTRIAL TRUCKS	EN 1175-1
BASIC ENVIRONMENTAL TESTING PROCEDURES	IEC 68-2-30 Damp Heat Cycle
PROTECTION CLASS	IP 54 Test IEC 60529 (with mating connector K1 installed)

8.10 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

8.11 PHYSICAL CHARACTERISTICS

8.11.1 WEIGHT

AC SuperDrive Model	Finned heatsink Weight Kg	Flat heatsink Weight Kg
ACSxx 10	4.2	4.3
ACSxx 15	5.9	6.1
ACSxx 20	7.7	8.0
ACSxx 25	9.4	9.7

8.11.2 DIMENSIONS

Figure 37 AC SuperDrive with fins. Figure 38 shows dimensions for AC SuperDrive model 10 to 25 and drilling pattern for the flat heatsink versions and surface roughness and surface flatness requirements for the flat heatsink versions. (Dimensions in mm).

AC SuperDrive Model				
Flat version	Y1	Y2	Y3	Y4
ACSxx 10	165	120	-	9
ACSxx 15	233.6	150	-	41.8
ACSxx 20	302.2	215	107.5	43.6
ACSxx 25	370.8	250	125	60.4
Finned version	Y1	X1	X2	X3
ACSxx 10	165	25.5	-	114
ACSxx 15	233.6	25.5	-	182.6
ACSxx 20	302.2	25.5	125.6	251.2
ACSxx 25	370.8	25.5	159.9	319.8

8.11.3 SURFACE REQUIREMENTS









Model		Tolerance	Roughness
ACSxx 10		0.1/270x165 mm	 Ra 1.6
ACSxx 15		0.1/270x233 mm	 Ra 1.6
ACSxx 20		0.1/270x302 mm	 Ra 1.6
ACSxx 25		0.1/270x370 mm	 Ra 1.6

Table 29 Roughness and flatness requirements for flat AC SuperDrive.

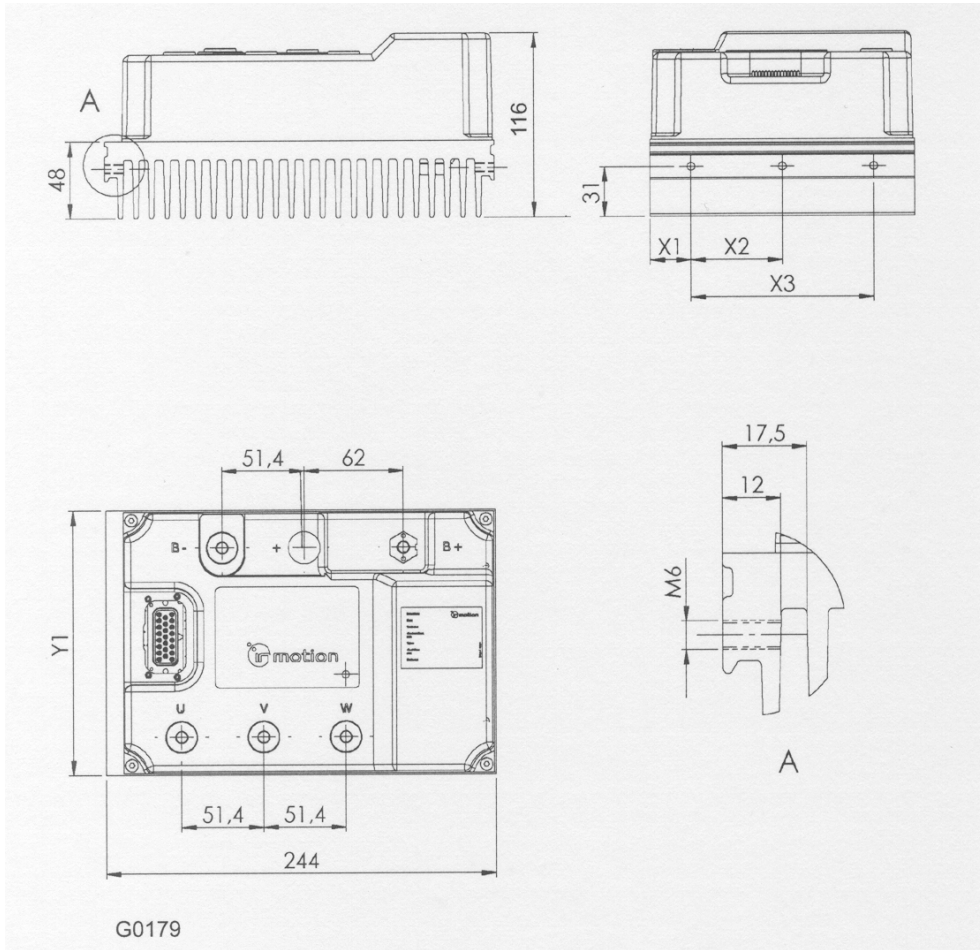


Figure 37. Dimensions for AC SuperDrive with finned heatsink (mm).

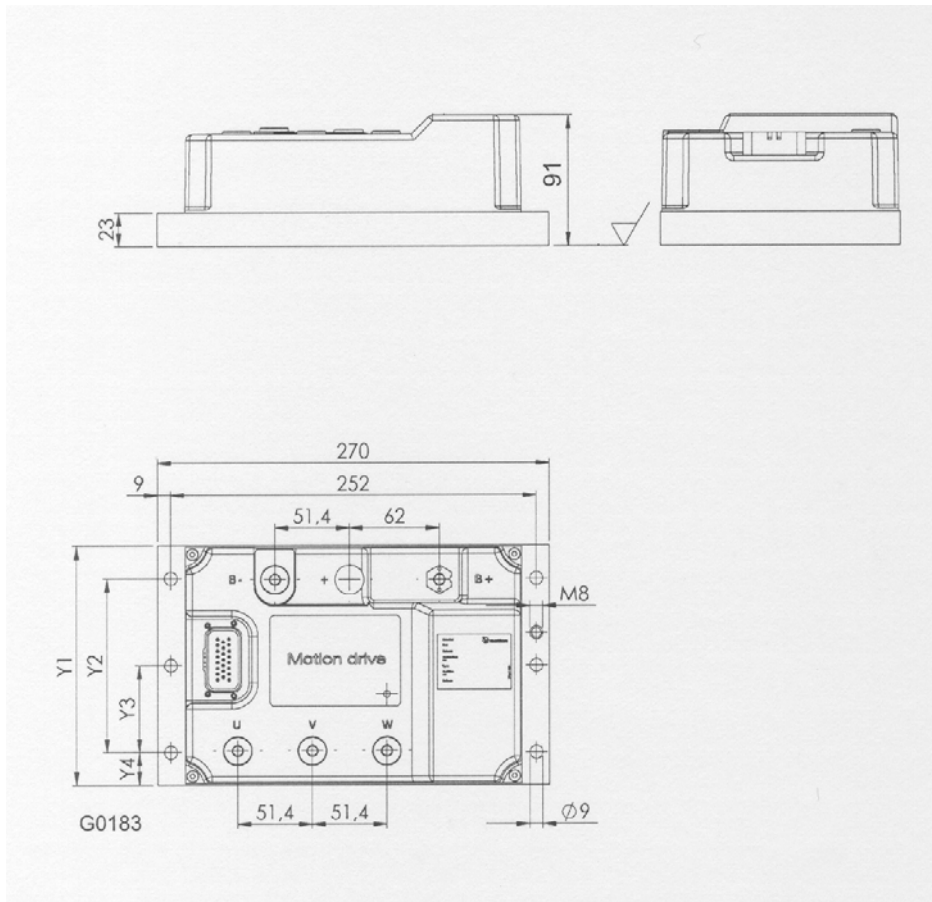


Figure 38. Dimensions and surface roughness for flat heatsink (mm).

Sales and service

Danaher Motion products are available worldwide through an extensive authorized distributor network. These distributors offer literature, technical assistance and a wide range of models off the shelf for fastest possible delivery.

Danaher Motion sales engineers are conveniently located to provide prompt attention to customers needs. Call the nearest office listed for ordering and application information or for the address of the closest authorized distributor.

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