**Gen4**

**Applications**

**Reference**

**Manual**

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Sevcon Ltd

Kingsway South

Gateshead, NE11 0QA England

Tel +44 (0)191 497 9000 Fax +44 (0)191 482 4223 sales.uk@sevcon.com

Sevcon, Inc.

155 Northboro Road

Southborough, MA 01772 USA

Tel (508) 281 5500

Fax (508) 281 5341

sales.us@sevcon.com

Sevcon SA

12 Rue Jean Poulmarch 95100 Argenteuil

France

Tel +33 (0)1 34 10 95 45 Fax +33 (0)1 34 10 61 38 sales.fr@sevcon.com

Sevcon Japan

4-12-1 Shinbashi

Minato-Ku, Tokyo 105-0004 Japan

Tel +81 (0) 3 (5408) 5670 Fax +81 (0) 3 (5408) 5677 sales.jp@sevcon.com

Sevcon Asia Ltd

4th Floor, Eun-Hyae Building 463-1, Sang-dong

Wonmee-gu, Bucheon City Kyunggi-do 420-030

Korea

Tel +82 (0)32 215 5070 Fax +82 (0)32 215 8027 sales.kr@sevcon.com

www.sevcon.com

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**Chapter 1: Introduction**

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**About Gen4 documentation**

This version of the manual

This version of the Gen4 manual replaces all previous versions. Sevcon has made every effort to ensure this document is complete and accurate at the time of printing. In accordance with our policy of continuing product improvement, all data in this document is subject to change or correction without prior notice.

Copyright

This manual is copyrighted 2009 by Tech/Ops Sevcon. All rights are 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 Tech/Ops Sevcon.

Scope of this manual

The Application Reference Manual provides important information on configuring lift and traction drive systems using Gen4 controllers as well as details on sizing and selecting system components, options and accessories.

The manual also presents important information about the Gen4 product range. Related documents

The following documents are available from Sevcon:

∙ The Object Dictionary providing important information about CANopen communication with Gen4.

∙ Device Configuration Files (DCF) and Electronic Data Sheets (EDS) for each Gen4 model and revision.

Drawings and units

Orthographic illustrations in this manual are drawn in Third Angle Projection. SI units are used throughout this manual.

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**Introduction**

Warnings, cautions and notes

Special attention must be paid to the information presented in Warnings, Cautions and Notes when they appear in this manual. Examples of the style and purpose of each are shown below:

**A WARNING is an instruction that draws attention to the risk of injury or death and tells you how to avoid the problem.** 

A CAUTION is an instruction that draws attention to the risk of damage to the product, process or surroundings. 

*A NOTE indicates important information that helps you make better use of your Sevcon product.*

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**Product identification label**

If you have a customized product your unique identifier will appear at the end of the Type number. When discussing technical issues with Sevcon always have your product‟s Type number, Part number and Serial number available. Figure 1 shows a typical product identification label.

|  |
| --- |

Figure 1 Product identification label

**Technical support**

For technical queries and application engineering support on this or any other Sevcon product please contact your nearest Sevcon sales office listed on the inside front cover of this manual. Alternatively you can submit enquiries and find the details of the nearest support center through the Sevcon website, www.sevcon.com.

**Product warranty**

Please refer to the terms and conditions of sale or contract under which the Gen4 was purchased for full details of the applicable warranty.

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**Chapter 2:**

**About the Gen4**

**Introduction**

Sevcon Gen4 controllers are designed to control 3-phase AC induction motors and Permanent Magnet AC (PMAC) motors in battery powered traction and pump applications. A range of models is available to suit a wide number of applications and cooling regimes.

The controller adapts its output current to suit the loading conditions and the ambient in which it is operating (temporarily shutting down if necessary). It will also protect itself if incorrectly wired.

Signal wiring and power connections have been designed to be as simple and straight forward as possible. Analog and digital signal inputs and outputs are provided for switches, sensors, contactors, hydraulic valves and CAN communications. These electrical signals can be mapped to Gen4‟s software functions to suit a wide range of traction and pump applications.

*Given Gen4’s mapping versatility it is important to ensure you map your application signals to the correct software functions (see ‘Manual object mapping’ on page 6-10). A common configuration is supplied by default which may suit your needs or act as a starting point for further configuration.* 

Configuration and control of Gen4 is fully customizable using Sevcon‟s Calibrator handset or DriveWizard, an intuitive Windows based configuration software tool.

A single green LED is provided to give a visual indication of the state of the controller. This signal can be replicated on a dashboard mounted light for example.

**Standard features and capabilities**

Available options

There are three mechanical package options (Figure 2) for the Gen4 controller at various voltage and current ratings.

Size 2 models Size 4 models Size 6 models

Figure 2 Mechanical package options

Intended use of the Gen4

The Gen4 motor controller can be used in any of these main applications for both pump and traction control:

2-2

**About the Gen4**

∙ Counterbalanced, warehouse and pedestrian fork lift trucks

(Classes 1 to 3, FLT1, 2 & 3)

∙ Airport ground support (AGS), including tow tractors

∙ Utility vehicles

∙ Burden carriers

∙ Sweepers and scrubbers

∙ Golf buggies/carts

∙ Neighborhood electric vehicles (NEV)

∙ Scooters

∙ Marine

Available accessories

The following accessories are available from Sevcon

∙ Loose equipment kit (connectors and pins) for Gen4

∙ Gen4 cooling kit

∙ CANopen Calibrator Handset

∙ SmartView™ display

∙ ClearView™display

∙ Hourmeters

∙ Contactors

∙ Fuses

∙ Drive Wizard - PC based configuration tool

∙ SCWiz – PC based motor characterisation tool

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**Overview of a truck drive system**

Each traction or pump application requires a number of system components. The main components (excluding control inputs such as throttle and seat switch) are shown in Figure 3. In this example there are two controllers, a traction motor and a hydraulic pump, however all the main components would be the same if controller 2 was also powering a traction motor.

Communication between the controllers is achieved using the CANopen protocol. This protocol also allows Gen4 to communicate with other non-Sevcon, CANopen compliant devices.

control fuse

isolator

key switch

line contactor

CAN bus

+ -

B

battery

Figure 3 Truck system components

B+ + signals B- B+ + signalsGen4 controller 1 Gen4 controller 2

M1 M2 M3 M1 M2 M3 3ø 3ø

motor pump

Signal power for the internal control circuits and software is derived from the battery via the control fuse and key switch as shown. No external in-rush current limiting is needed as long as Gen4 is used to control the line contactor and hence the timing of its closure. The software controls the start up sequence in this order:

1. Charge the input capacitors to within a user definable percentage (using 5820h) of battery voltage (via the key switch signal line).

2. Close line contactor.

3. Generate output to the motor as demanded.

A line input fuse can be mounted on the body of the controller. The „B+‟ terminal is a dummy terminal. If the fuse is mounted elsewhere, connections from the battery positive are made to the controller „+‟ terminal see “On-board fuse mounting” section.

**Principles of operation**

2-4

Functional description

**About the Gen4**

The main function of Gen4 is to control the power to 3-phase squirrel-cage AC induction or PMAC motors in electric vehicles. Four-quadrant control of motor torque and speed (driving and braking torque in the forward and reverse directions) is allowed without the need for directional contactors. Regenerative braking is used to recover kinetic energy which is converted into electrical energy for storage in the battery.

In a traction application control commands are made by the driver using a combination of digital controls (direction, foot switch, seat switch, etc.) and analog controls (throttle and foot brake). The controller provides all the functions necessary to validate the driver‟s commands and to profile the demand for speed and torque according to stored parameters.

Throttle inputs can be configured as speed or torque demands with throttle-dependent speed limits: in either case, a torque demand is continually calculated to take account of pre-set limits on the level and rate-of-change of torque. The torque demand is used to calculate current demands; that is, the controller calculates what currents will be required within the motor to generate the required torque.

There are two distinct components of the current, known as the d-q axis currents, which control current flow in the motor. The d-axis current is responsible for producing magnetic flux, but does not by itself produce torque. The q-axis current represents the torque-producing current.

*When a vehicle is ready to drive, but no torque is being demanded by the driver, the d-axis or magnetizing current will be present in the motor so that the vehicle will respond immediately to a torque demand. To save energy the magnetizing current is removed if the vehicle is stationary and no torque has been demanded after a set period.* 

Measured phase currents and current demands id and iq, the d-q axis currents, are used as part of a closed-loop control system to calculate the necessary voltage demands for each phase of the motor. Voltage demands are then turned into PWM demands for each phase using the Space Vector Modulation (SVM) technique. SVM ensures optimum use of the power semiconductors.

Power conversion section

The power conversion section of Gen4 employs a 6-switch MOSFET bridge operating at an effective frequency of either 16 kHz or 24kHz (the PWM frequency is set using 5830h). Excellent electrical and thermal efficiency is achieved by:

∙ Minimization of thermal resistances.

∙ Use of the latest MOSFET technology

∙ Internal thermal protection (if temperatures are excessive, output torque is reduced). ∙ Overcurrent protection using device characteristics.

∙ Internal measurement of output current.

∙ Overvoltage trip in the event of regenerative braking raising battery voltage to unsafe levels.

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Dual traction motor

In the case of dual traction motors, there is additional processing of the associated steering signal (from a potentiometer or switches) in order to generate separate torque demands for the left and right motors of the vehicle. This allows the two motors to be operated at different speeds, which greatly assists in turning the vehicle and prevents wheel scrub. After the torque demands have been generated, the operation of each motor control system is as described in the case of a single traction motor.

Pump motors

Pump motor control is similar to traction motor control, although motion is requested using a different combination of switches.

Interfaces

In addition to its motor control functions, Gen4 offers many other functions designed to interface with electric vehicles. A variety of digital and analog input sources are supported, as listed in „Signal connections‟ on page 3-11.

Voltage and current control of up to three contactors or proportional valves is provided by Gen4, and includes built-in freewheeling diodes for spike suppression. All I/O on the Gen4 controller is protected against short-circuit to the battery positive and negative terminals.

Connectivity and interoperability with other system devices (for example another Gen4 controller) using a CANbus and the CANopen protocol is provided. In addition to in-service operation, the CANopen protocol allows the controller to be commissioned using the Calibrator handset or Sevcon‟s DriveWizard tool. In addition Sevcon‟s SCWiz PC based tool provides the function to self-characterise most induction motors and hence simplify the process of putting a new motor into service.

For simple visual diagnosis of system faults and to monitor system status, a green LED is provided on the body of the controller. It is continuously lit when there is no fault but flashes a different number of times, in a repeated pattern, when there is a fault. The number of flashes indicates the type of fault (see „‟ on page 1).

Master-slave operation

The Gen4 controller contains both master and slave functions as shown in Figure 4. They operate as follows:

∙ **Slave function:** implements the CANopen Generic I/O Profile (DS401) and the Drives and Motion Control Profile (DSP402).

∙ **Master function:** implements vehicle functionality (traction and pump control) and CANopen network management.

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Controller

master

function

CANopen

**About the Gen4**

I/O

slave

motor slave

to motors, switches,

pedals etc

Figure 4 Single controller

Torque mode

In this mode Gen4 maintains the motor torque output at a constant value for a given throttle position. This is similar to DC motors (in particular, series wound DC motors) and provides a driving experience like a car. To prevent excessive speed when the load torque is low, for example when driving down hill, a maximum vehicle speed can be set.

Speed mode

**Speed mode (or speed control) is not recommended for on-highway vehicles as it can cause the traction motor/wheel to remain locked or brake severely if the wheel is momentarily locked due to loss of traction on a slippery surface and/or mechanical braking.** 

In this mode Gen4 maintains the motor at a constant speed for a given throttle position as long as sufficient torque is available. Speed mode differs from torque mode in that the torque value applied to the motor is calculated by the controller based on the operator‟s requested speed (determined by throttle position) and the vehicle‟s actual speed. This mode is useful where accurate speed control is required irrespective of the motor torque.

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**Safety and protective functions**

General

**Electric vehicles can be dangerous. All testing, fault-finding and adjustment should be carried out by competent personnel. The drive wheels should be off the floor and free to rotate during the following procedures. The vehicle manufacturer's manual should be consulted before any operation is attempted.** 

**The battery must be disconnected before replacing the controller. After the battery has been disconnected wait 30 seconds for the internal capacitors to discharge before handling the controller.** 

**Never connect the controller to a battery with vent caps removed as an arc may occur due to the controller's internal capacitance when it is first connected.** 

As blow-out magnets are fitted to contactors (except 24V) ensure that no magnetic particles can accumulate in the contact gaps and cause malfunction. Ensure that contactors are wired with the correct polarity to their power terminals as indicated by the + sign on the top molding. 

Do not attempt to open the controller as there are no serviceable components. Opening the controller will invalidate the warranty. 

Use cables of the appropriate rating and fuse them according to the applicable national vehicle and electrical codes. 

Where appropriate use of a suitable line contactor should be considered.



Electric vehicles are subject to national and international standards of construction and operation which must be observed. It is the responsibility of the vehicle manufacturer to identify the correct standards and ensure that their vehicle meets these standards. As a major electrical control component the role of the Gen4 motor controller should be carefully considered and relevant safety precautions taken. The Gen4 has several features which can be configured to help the system integrator to meet vehicle safety standards. Sevcon accepts no responsibility for incorrect application of their products.

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**About the Gen4**

On-Highway Vehicles

General

This applies to all on-highway vehicles, such as motorcycles and cars.

The installer must ensure an appropriate controller configuration is set to ensure that the vehicle remains in a safe condition, even in the event of a fault.

Inputs

Always ensure drive inputs have adequate protection. Inputs such as the throttle should have appropriate wire-off detection configured. Single point failures should never cause an unsafe condition.

Gen4 supports wire-off detection on all analogue inputs, and it contains various safety interlocks to prevent unexpected drive due to a wiring fault (e.g. FS1 switch, dual throttle inputs).

Sevcon recommends that the following features are enabled for all applications:

• Wire-off detection on analogue inputs, particularly the throttle.

• A valid analogue input voltage which is more than 0.5V from wire off limits

• Appropriate safety interlocks to ensure a single point of failure cannot cause an unsafe driving condition.

Refer to sections Analog inputs (page 6-14) and Vehicle performance configuration (page 6-17) for more information.

Notes on Features

The Gen4 is a generic motor controller intended for use in both highway AND non-highway industrial applications. Not all of the controller features are suitable for an on-highway vehicle. Some features, if activated, could lead to the controller forcing a motor condition that is not directly requested by the throttle, such as undesired drive or harsher than expected braking.

Sevcon recommends that the following features are DISABLED for any on-highway applications: • Proportional Speed Limit1.

• Hill Hold1.

• Controlled Roll-Off1.

• Speed mode (or speed control)1.

• Electromechanical Brake output1.

• Inching2.

• Belly switch2.

• Unused Driveability Profiles3.

NOTES:

1. These features can cause the traction motor/wheel to remain locked or brake severely if the wheel is momentarily locked due to loss of traction on a slippery surface and/or mechanical braking.

2. These features can cause unexpected drive if accidentally activated.

3. This feature can cause a sudden reduction in maximum speed if a driveability profile is accidentally activated and is incorrectly configured.

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In addition, the following features must be configured correctly

• Steering map, if used to reduce maximum outer wheel speed with steering angle.2-10

Fault detection and handling

**About the Gen4**

There are five categories of faults as described in Table 1. For a detailed list of faults see Table 8 on page 7-9.

| **Fault severity** | **Controller latched off until** | **Consequences** |
| --- | --- | --- |
| Return to base  (RTB) | Cleared by Sevcon  personnel | Immediate shut down of the system with the exception of the power steering if needed. Power is removed to nearly all external components. |
| Very severe (VS) | Cleared by authorized service personnel | Immediate shut down of the system with the exception of the power steering if needed. Power is removed to nearly all external components. |
| Severe (S) | Keyswitch recycled  (turned off then on) | Immediate shut down of the system with the exception of the power steering if needed. Power is removed to nearly all external components. |
| Drive-inhibit (DI) | User deselects all drive switches before  reselecting | Neutral brakes or coasts the traction motor(s) to a stop. The fault prevents the operator initiating drive, but does not inhibit braking function, in particular, controlled roll-off braking. |
| Information (I) | Not latched | Information faults do not require immediate action, although some cutback of power or speed may occur. |

Table 1 Fault categories

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**Chapter 3: Installation**

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**Mounting Gen4**

Orientation

The controller can be mounted in any orientation.

Clearance for LED access

If you want an operator of your vehicle to be able to view the onboard LED, it is advisable to consider the line of sight to the LED at this time.

Mounting hole pattern

Flatness of mounting surfaces: 0.2mm

Failure to comply with this flatness specification can cause deformation of the frame and damage to the product. 

Equipment required:

∙ 4 x M6 socket cap head bolts, nuts and spring washers. Bolts need to be long enough to pass through 12 or 20 mm of Gen4 baseplate (depending on controller type) and your mounting surface thickness.

∙ T hand-socket wrench or Allen key

∙ Thermal grease

Recommended torque setting: 10 Nm ± 2 Nm

3-2

**Installation**

Thermal grease application

Spread a layer of thermal grease (such as Dow Corning 340) as described below, before bolting to your mounting surface.

∙ Thermal compound should be applied with a small soft paint roller to ensures an even spread of thermal compound.

∙ The most appropriate thickness will look white but with a greyish colour still showing through from the controller base or vehicle mounting face material. *It should be noted that too little thermal compound will not fill all gaps left the flatness mismatch of the contact surfaces, but too much thermal compound may prevent the gap from closing up when tightening.*

∙ It is recommended that thermal compound is applied to both the Controller base and the vehicle/panel/boost plate surfaces.

∙ The controller should then be placed onto the vehicle/panel/heatsink.

∙ It is important that the two surfaces are then rubbed together in order to help transfer the thermal compound between the two surface.

∙ The entire assembly is then bolted together at all mounting holes.

An example of a good thermal compound spreading can be seen in the photo below:- How effective the spreading technique is can be checked by removing the controller and inspecting the paste residue left on the mounting faces. On a well applied paste application, the controller will be difficult to remove and a rippled surface will be left on the paste surface as shown (magnified) below:-

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**Cooling requirements**

To ensure you get the maximum performance from your Gen4 controller:

∙ Keep it away from other heat generating devices on the vehicle

∙ Maintain its ambient operating temperature below the specified maximum (see „Operating environment‟ on page 4-6)

To obtain maximum performance it is important to keep Gen4‟s base plate within the operating temperature range. To do this, mount Gen4 to a surface capable of conducting away the waste heat. Finned heatsinks are considerably better at doing ths than flat plates. For example, a finned heatsink used at Sevcon has a footprint of 330mm x 200mm and thermal resistance of 0.3°C/W, whereas a plate approximately 420 mm x 270 mm x 9.5 mm will give approximately the same thermal performance (0.3°C/W). Ratings achievable with conductive heatsinking are shown in Figure 11 on page 4-3.

In Sevcon‟s experience the thermal resistance of the stand-alone Gen4 packages and achievable thermal resistances to ambient using conductive heatsinking are as shown in the table below. These are given as a guide: actual performance in an application must be verified.

| **Gen4 Size** | **Thermal resistance without additional heatsinking (°C/W)** | **Thermal resistance**  **achievable with finned heatsink (°C/W)** | **Dimension of finned heatsink (W x L)** |
| --- | --- | --- | --- |
| Size 2 | 0.7 | 0.5 | 250mm x 180mm |
| Size 4 | 0.6 | 0.3 | 330mm x 200mm |
| Size 6 | 0.5 | 0.2 | 330mm x 280mm |

Cooling performance is affected by mounting surface flatness and the thermal transfer between mounting surface and Gen4. Ensure your application of thermal grease is effective and your mounting surface meets the flatness figures as described in the „Mounting‟ section above.

3-4

**Installation**

**EMC guidelines**

The following guidelines are intended to help vehicle manufacturers to meet the requirements of the EC directive 89/336/EEC for Electromagnetic Compatibility. Any high speed switch is capable of generating harmonics at frequencies that are many multiples of its basic operating frequency. It is the objective of a good installation to contain or absorb the resultant emissions. All wiring is capable of acting as a receiving or transmitting antenna. Arrange wiring to take maximum advantage of the structural metal work inherent in most vehicles. Link vehicle metalwork with conductive braids.

Power cables

Route all cable within the vehicle framework and keep as low in the structure as is practical - a cable run within a main chassis member is better screened from the environment than one routed through or adjacent to an overhead guard. Keep cables short to minimize emitting and receiving surfaces. Shielding by the structure may not always be sufficient - cables run through metal shrouds may be required to contain emissions.

Parallel runs of cables in common circuits can serve to cancel emissions - the battery positive and negative cables following similar paths is an example. Tie all cables into a fixed layout and do not deviate from the approved layout in production vehicles. A re-routed battery cable could negate any approvals obtained.

Signal cables

Keep all wiring harnesses short and route wiring close to vehicle metalwork. Keep all signal wires clear of power cables and consider the use of screened cable. Keep control wiring clear of power cables when it carries analogue information - for example, accelerator wiring. Tie all wiring securely and ensure it always follows the same layout.

Controller

Thermal and EMC requirements tend to be in opposition. Additional insulation between the controller assembly and the vehicle frame work reduces capacitive coupling and hence emissions but tends to reduce thermal ratings. Establish a working balance by experiment. Document the complete installation, in detail, and faithfully reproduce on it all production vehicles. Before making changes, consider the effect on EMC compliance. A simple cost reduction change could have a significant negative effect on the EMC compliance of a vehicle.

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**Connecting power cables**

See also „EMC guidelines‟ on page 3-5.

Battery and motor connections

Cables carrying high AC currents are subject to alternating forces and may require support in the cable harness to avoid long-term fatigue. 

Equipment required for **size 4 or 6 models**:

∙ Cables sized to suit the controller and application (see table below)

∙ M8 crimp ring lugs

∙ Crimp tool

∙ M8 wrench

Torque setting: 11 Nm ± 2 Nm

Equipment required for **size 2 models**:

∙ Cables sized to suit the controller and application (see table below)

∙ M6 crimp ring lugs

∙ Crimp tool

∙ M6 wrench

Torque setting: 7 Nm ± 1 Nm

Consider cable routing before making connections.

∙ Keep cable runs short

∙ Minimize current loops by keeping positive and negative cables as close together as possible.

∙ Route cables away from the LED if you intend to make this visible under normal operating conditions.

Connect your power cables using the bolts supplied. They are sized to clamp one ring lug thickness. Use a longer bolt if you are fastening more than one ring lug. You need thread engagement of at least 10 mm and the maximum penetration is 15 mm.

If you use a bolt which is too long, damage to the terminal and overheating of the connection may occur. If you use a bolt which is too short and there isn‟t enough thread engagement you may damage the threads. 

Cable sizes

When deciding on power cable diameter, consideration must be given to cable length, grouping of cables, the maximum allowable temperature rise and the temperature rating of the chosen cable. 

3-6

**Installation**

The following table gives guidance on the cable size needed for various currents in welding cable, not grouped with other cables, in 25°C ambient with 60°C temperature rise on the cable surface.

| **Gen4 average (rms)**  **current** | **Cable sizes** | |
| --- | --- | --- |
| **metric** | **US**  **(approx**  **equivalent)** |
| 180 A | 25 mm2 | 4 AWG |
| 225 A | 35 mm2 | 2 AWG |
| 280 A | 50 mm2 | 1 AWG |
| 350 A | 70 mm2 | 2/0 AWG |

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**On-board fuse mounting**

You can mount your main input protection fuse directly onto the controller body as shown below . Select the appropriate fuse from the table below. Connect the battery positive cable to the B+ terminal. Connecting to the end marked „+‟ (or un-named in the case of size 2) will leave your installation without a fuse unless located elsewhere in the system. The B+ terminal is a dummy terminal to allow fuse connection only and has no internal connection.

Figure 5 On-board fuse mounting – size 2 models

|  |
| --- |

Figure 6 On-board fuse mounting – size 4 models

3-8

**Installation**

|  |
| --- |

Figure 7 On-board fuse mounting – size 6 models

Fuse rating and selection

On-board fuse dimensions are in accordance with DIN43560/1

| **Gen4 input voltage** | **Gen4 peak output current** | **Fuse rating** | **Sevcon part number** |
| --- | --- | --- | --- |
| 24V/36 V | 300 A | 325 A | 858/32044 |
| 450 A | 425 A | 858/81990 |
| 650 A | 750 A | 858/33021 |
| 36V/48 V | 275 A | 250 A | 858/29043 |
| 450 A | 425 A | 858/81990 |
| 650 A | 750 A | 858/33021 |
| 72V/80 V | 180 A | 200 A | 858/83339 |
| 350 A | 355 A | 858/32045 |
| 550 A | 500 A | 858/32043 |

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**Signal wiring**

Assemble your wiring harness using wire of the sizes recommended below and the Sevcon loose connector kit (P/N 661/27091). The use of twisted pair and in some cases twisted-screened cables is recommended for the speed sensor and CANbus wiring.

To make a connection, gently push the connector housing onto the appropriate mating half on the Gen4. Never force a connector. Connectors are keyed to prevent incorrect insertion.

Twisted, shielded wire is recommended. Keep signals away from power cables to avoid interference. See also „EMC guidelines‟ on page 3-5.

Signal wire sizes

Use wire between 0.5 mm² (20 AWG) and 1.5 mm² (16 AWG) for all signal wiring. Single twisted pair cable is readily available in 0.5 mm² (20 AWG).

CANbus termination

See also „EMC guidelines‟ on page 3-5.

If your system has more than one CAN node, connect the nodes in a „daisy chain‟ arrangement (Figure 8) and terminate the connections of the two end nodes with a 120 Ω resistor. If the end node is a Gen4, link pins 2 and 24 on the customer connector, a 120 Ω resistor is built into the controller. If you have a single node system the termination resistor should be connected so that the bus operates correctly when

configuration tools are used.

120 Ω

link

CANbus

P

P

n

n

i

i

2

2

4

Gen4 Gen4

Other CAN node

Figure 8 CAN node termination3-10

**Installation**

**Signal connections**

Signal connections are made to Gen4 via a 35 way AMPSeal connector.

**1**

**12**

**13 23**

**24**

Figure 9 Customer Connector

**35**

Pins are protected against short-circuits to the battery positive or negative terminals.

Inserting contacts into connector housing pierces the sealing diaphragm to make the seal to the wire. To maintain IP rating, unused positions must be sealed with appropriate hardware (available from Tyco) if a contact is inserted and then subsequently removed.

| **Pin** | **Name** | **Type** | **What to connect** | **Maximum**  **rating** | **Comment** |
| --- | --- | --- | --- | --- | --- |
| 1 | Key switch in | Power | From „dead‟ side of key switch via suitable fuse | 7A  (Total of all  contactor  output  currents plus 1.0A) | This input supplies power from the battery for all the logic circuits.  The unit cannot operate  without “Key switch in”  supply.  Pins 1 and 6 (and 10 on Size 4 & 6 models) are connected together internally and can be used individually or in parallel. |
| 2 | CAN  termination | Comms | To terminate a Gen4 CAN node link pin 2 to pin 24. This connects a 120Ω  termination resistor, mounted inside the controller, across the CANbus. | | Make the connection only if the Gen4 is physically at the end of the CANbus network (see „CANbus termination‟ on  page 3-10. |
| 3 | Contactor  out 1 | Out | To the switched low side of contactor or valve coil. Contactor out 1 usually drives the line contactor. (DO NOT USE WITH CAPACITIVE LOADS). | 2.0A per  output,  subject to a  limit of 6A for the total of all the outputs.  V = Vb | This output provides low side voltage or current control to the load depending on  configuration.  The output goes low or is chopped to activate the load. It goes high (to Vb) to de  activate the load. |
| 4 | Output 1  Supply + | Power | To one end (high side) of a contactor to be  controlled by Contactor out 1 | 2A | This output feeds power to the contactors. The output is at battery voltage. |
| 5 | Encoder  “U” | Digital  pulse | Position encoder | 10V | Use in conjunction with “V” and “W” for PMAC motors. |

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| **Pin** | **Name** | **Type** | **What to connect** | **Maximum**  **rating** | **Comment** |
| --- | --- | --- | --- | --- | --- |
| 6 | Key-switch in | Power | From „dead‟ side of key switch via suitable fuse | 7A  (Total of all  contactor  output  currents plus 1.0A) | This input supplies power from the battery for all the logic circuits.  The unit cannot operate  without “Key switch in”  supply.  Pins 1 and 6 (and 10 on Size 4 & 6 models) are connected together internally and can be used individually or in parallel. |
| 7 | Contactor  out 2 | Out | To the switched low side of contactor or valve coil. (DO NOT USE WITH CAPACITIVE LOADS). | 2.0A per  output,  subject to a  limit of 6A for the total of all the outputs.  V = Vb | This output provides low side voltage or current control to the load depending on  configuration.  The output goes low or is chopped to activate the load. It goes high (to Vb) to de  activate the load. |
| 8 | Output 2  Supply + | Power | To one end (high side) of a contactor to be  controlled by Contactor out 2 | 2A | This output feeds power to the contactors. The output is at battery voltage. |
| 9 | Digital  Input 6 | Digital | From digital switch  input 6. | Type B  V = Vb  See Table 3 | See note to Table 3 |
| 10 | Size 2  models:  5V supply  output | Power | 5Vsupply output | I = 100mA.  V = 5V | This output can be used to power transducers or similar devices at 5V and up to  100mA. |
| Size 4 & 6  models:  Key switch input | Power | From „dead‟ side of key switch via suitable fuse | 7A  (Total of all  contactor  output  currents plus 1.0A) | This input supplies power from the battery for all the logic circuits.  The unit cannot operate  without “Key switch in”  supply.  Pins 1, 6 and 10 are connected together internally and can be used individually or in parallel. |
| 11 | Contactor  out 3 | Out | To the switched low side of contactor or valve coil. (DO NOT USE WITH CAPACITIVE LOADS). | 2.0A per  output,  subject to a  limit of 6A for the total of all the outputs.  V = Vb | This output provides low side voltage or current control to the load depending on  configuration.  The output goes low or is chopped to activate the load. It goes high (to Vb) to de  activate the load. |

3-12

**Installation**

| **Pin** | **Name** | **Type** | **What to connect** | **Maximum**  **rating** | **Comment** |
| --- | --- | --- | --- | --- | --- |
| 12 | Output 3  Supply + | Power | To one end (high side) of a contactor to be  controlled by Contactor out 3 | 2A | This output feeds power to the contactors. The output is at battery voltage. |
| 13 | CAN High | Comms | CANbus High signal | V = 5 V | Maximum bus speed 1  Mbits/sec  Alternative connection to pin 16 |
| 14 | Encoder A Input | Digital  pulse | From the speed encoder A channel | I = 25 mA  (internally  limited)  V = 8 V (for  current  source  encoders)  V = 2.5V or  5V (for open collector  encoders) | Check the speed encoder  signals have the correct  number of pulses per  revolution.  Check Gen4 is configured for the type of encoder you are using (open-collector or  current-source) |
| 15 | Encoder  power  supply - | Power | To the negative supply input (0 V) of the speed encoder | I = 100 mA  V = 0.5 V | We recommend the use of screened cable for the encoder wiring. Connect the screen to this pin only along with the negative supply. |
| 16 | CAN High | Comms | CANbus High signal | V = 5 V | Maximum bus speed 1  Mbits/s.  Alternative connection to pin 13 |
| 17 | Encoder  “V” | Digital  pulse | Position encoder | 10V | Use in conjunction with “U” and “W” for PMAC motors. |
| 18 | Digital  Input 1 | Digital | From digital switch  input 1.  In a basic configuration this is usually the forward switch. | Type A  V = Vb  See Table 3 | See note to Table 3 |
| 19 | Digital  Input 3 | Digital | From digital switch  input 3.  In a basic configuration this is usually the foot switch (FS1). | Type A  V = Vb  See Table 3 | See note to Table 3 |
| 20 | Digital  Input 5 | Digital | From digital switch  input 5. | Type B  V = Vb  See Table 3 | See note to Table 3 |

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| **Pin** | **Name** | **Type** | **What to connect** | **Maximum**  **rating** | **Comment** |
| --- | --- | --- | --- | --- | --- |
| 21 | Digital  Input 8 | Digital | From digital switch  input 8. | Type B  V = Vb  See Table 3 | See note to Table 3.  Alternative: Sin input from Sin-Cos analogue encoder, only if specified in h/w build |
| 22 | Pot. 1  wiper in | Analog | From potentiometer 1 wiper. | V = 9.5 V  Zin = 82 kΩ (24V/36V and 36V/48V  models)  Zin = 100 kΩ (24V/36V and 36V/48V  models) | Suitable for potentiometers in the range 500 Ω to 10 kΩ, or voltage-output device (e.g. Sevcon linear accelerator) 0 to 5 V or 0 to 10 V.  Ensure that at least 0.5V  margin exists between the maximum valid throttle and the wire-off threshold |
| 23 | Pot. 2  wiper in | Analog | From potentiometer 2 wiper. | V = 9.5 V  Zin = 82 kΩ (24V/36V and 36V/48V  models)  Zin = 100 kΩ (24V/36V and 36V/48V  models) | Suitable for potentiometers in the range 500 Ω to 10 kΩ, or voltage-output device (e.g. Sevcon linear accelerator) 0 to 5 V or 0 to 10 V.  Ensure that at least 0.5V  margin exists between the maximum valid throttle and the wire-off threshold |
| 24 | CAN Low | Comms | CANbus Low signal | V = 5 V | Maximum bus speed 1  Mbits/s.  Alternative connection to pin 27 |
| 25 | Encoder B Input | Digital  pulse | From the speed encoder B channel | I = 25 mA  (internally  limited)  V = 8 V (for  current  source  encoders)  V = 2.5V or  5V (for open collector  encoders) |  |
| 26 | Encoder  power  supply + | Power | To the positive supply input of the speed encoder | I = 100 mA  V = 5V or  10V software selectable | Check the speed encoder you use is compatible with Gen4. See page 6-12 for  configuration details. |

3-14

**Installation**

| **Pin** | **Name** | **Type** | **What to connect** | **Maximum**  **rating** | **Comment** |
| --- | --- | --- | --- | --- | --- |
| 27 | CAN Low | Comms | CANbus Low signal | V = 5 V | Maximum bus speed 1  Mbits/s.  Alternative connection to pin 24 |
| 28 | CAN  power  supply + | Power | To CAN device requiring external supply | V = 24 V  I = 100 mA | Check that the CAN device power supply requirement is suitable for Gen4. |
| 29 | Encoder  “W” | Digital  pulse | Position encoder | 10V | Use in conjunction with “U” and “V” for PMAC motors. |
| 30 | Digital  Input 2 | Digital | From digital switch  input 2.  In a basic configuration this is usually the reverse switch. | Type A  V = Vb  See Table 3 | See note to Table 3 |
| 31 | Digital  Input 4 | Digital | From digital switch  input 4.  In a basic configuration this is usually the seat switch. | Type A  V = Vb  See Table 3 | See note to Table 3 |
| 32 | Digital  Input 7 | Digital | From digital switch  input 7. | Type B  V = Vb  See Table 3 | See note to Table 3 |
| 33 | Motor  thermistor in | Analog | From a thermistor device mounted inside the motor | V = 5 V  (via 2.2 kΩ  internal pull up resistor) | A NTC thermistor having a resistance of approximately 2.2 kΩ at 100°C will give best sensitivity.  Connect the other lead of the thermistor to the B- terminal of the Gen4 controller.  Can also be used as an  additional analog input |
| 34 | Pot. 1  power  supply + | Power | Supply feed to  potentiometer 1. In a  basic configuration this is the throttle. | V = 10 V  I = 15 mA | Suitable for potentiometers in the range 500 Ω to 10 kΩ |
| 35 | Pot. 2  power  supply + | Power | Supply feed to  potentiometer 2. | V = 10 V  I = 15 mA | Suitable for potentiometers in the range 500 Ω to 10 kΩ. Alternative: Cos input from Sin-Cos analogue encoder, only if specified in h/w build |

Table 2 Connector A pin out and wiring information

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| **Controller**  **voltage** | **Digital Input**  **Type** | **Impedance to B+** | **Impedance to B** |
| --- | --- | --- | --- |
| 24V/36V | A | 9k | 9k |
|  | B | 13k | 9k |
| 36V/48V | A | 16k | 16k |
|  | B | 24k | 16k |
| 72V/80V | A | 44k | 44k |
|  | B | 66k | 44k |

Table 3: Impedance at Digital Input Pins

Note to Table 3:

Configure the digital input switches as active-high (switched to Vb) or active-low (switched to battery negative). Configuration applies to all digital input switches (1 to 8) i.e. they are all active-high or all active-low. See section Digital inputs (page 6-14) for more details.

When a switch is open the digital input pin sits at 0.5 x Vb. The input sinks current in active-high configurations and sources current in active-low configurations.

3-16

**Installation**

**Calibrator connections (Size 2 models only)**

Calibrator connections are made to Gen4 via a 6 way Minifit Junior connector accessed by lifting rubber cover. **Ensure cover is fully engaged after use to maintain IP rating**.



Figure 10 Calibrator Connector

Pin 1 and pin 3 – 6 are protected against short-circuits to the battery positive or negative terminals.

| **Pin** | **Name** | **Type** | **What to connect** | **Maximum rating** | **Comment** |
| --- | --- | --- | --- | --- | --- |
| 1 | CAN  Term. | Comms | Normally no connection. This pin can be connected to pin 3 if the controller wiring does not  terminate the bus on the 35-way connector and the equipment being connected via the calibrator port does require termination. | V = 5 V | Internally connected to CANH via 120Ohm. |
| 2 | 0V | 0V | Connects the controller 0V to the 0V of the calibrator. |  | Internally connected to the B terminal. |
| 3 | CAN  Low | Comms | Normally no connection. This pin can be connected to pin 1 if the controller wiring does not  terminate the bus on the 35-way connector and the equipment being connected via the calibrator port does require termination. | V = 5 V | Maximum bus speed 1  Mbits/s. |
| 4 | CAN  power  supply + | Power | To CAN device requiring 24V supply | V = 24 V  I = 100 mA | Check that the CAN device power supply requirement is suitable for Gen4. |
| 5 | CAN  High | Comms | CANbus High signal | V = 5 V | Maximum bus speed 1  Mbits/s. |
| 6 | CAN  Low | Comms | CANbus Low signal | V = 5 V | Maximum bus speed 1  Mbits/s. |

Table 4 Connector B pin out and wiring information

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**Chapter 4:**

**Specification**

**Electrical**

Input voltage

|  | **24V only**  **(Size 2 24V)** | **24/36V**  **controllers** | **36/48V**  **controllers** | **72/80V**  **controllers** |
| --- | --- | --- | --- | --- |
| Conventional  working voltage range  (Note 1) | 16.8V to 28.8V | 16.8V to 43.2V | 25.2V to 57.6V | 50.4V to 96V |
| Working  voltage limits  (Note 2) | 12.7V to 34.8V | 12.7V to 52.2V | 19.3 V to 69.6 V | 39.1 V to 116 V |
| Non-operational overvoltage  limits: | 39.6V | 59.4V | 79.2 V | 132 V |
| Battery voltage droop: | Vnom to 0.5 x Vnom for 100 ms | | | |
| Input  protection: | Input protected against reverse connection of battery | | | |

Note 1: Conventionally the controller may be set to operate without cutback in the range 70% to 120% of the nominal battery voltage, although cutback parameters may be used to set cutbacks higher or lower than this range. Cutbacks are set by the user for various reasons, including:

∙ Battery protection against high current in deep discharge condition

∙ Providing smoothly reducing performance at extremes of working voltage range, rather than a sudden loss of function

Note 2: Working voltage range outside which the controller will be non-operational. Output protection

| Output current: | Reduced automatically from peak to continuous rating depending on the time a peak load is applied to the controller (see Figure 11 on page4-3). Reduced automatically if operated outside normal temperature range. |
| --- | --- |
| Short-circuit: | Protected against any motor phase to B- or B+ at power-up.  Protected against any motor phase to another motor phase at any time during operation.  At switch-on Gen4 detects valid output loads are present before applying drive current. |

Repetitive short circuits may damage the controller.



4-2

Output ratings

**Specification**

| **Input**  **(Vdc)** | **Function** | **Short term**  **rating\* (A rms)** | **Continuous**  **rating\*\* (A rms)** |
| --- | --- | --- | --- |
| 24 | Single traction size 2 | 300 | 120 |
| 24/36 | Single traction size 4 | 450 | 180 |
| Single traction size 6 | 650 | 260 |
| 36/48 | Single traction size 2 | 275 | 110 |
| Single traction size 4 | 450 | 180 |
| Single traction size 6 | 650 | 260 |
| 72/80 | Single traction size 2 | 180 | 75 |
| Single traction size 4 | 350 | 140 |
| Single traction size 6 | 550 | 210 |

\*2 minute rating (lower ratings are possible for longer periods; see example in Figure 11) \*\* 1 hour minimum without forced-air cooling

Size 2 long-term rating achievable with finned heatsink approx 250mm x 180mm, 0.5°C/W Size 4 long-term rating achievable with finned heatsink approx 330mm x 200mm, 0.3°C/W Size 6 long-term rating achievable with finned heatsink approx 330mm x 280mm, 0.2°C/W

Figure 11 Output current available for various durations of sustained current demand

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CAN interface

| CAN protocol: | CANopen profiles DS301, DS401 and DSP402 are supported. Physical layer uses ISO11898-2. |
| --- | --- |
| Baud rates supported: | 1 Mbits/s (default), 500 kbits/s, 250 kbits/s, 125 kbits/s, 100 kbits/s, 50 kbits/s and 20 kbits/s. |

Control inputs and outputs

| Digital inputs: | 8 digital switch inputs (software configurable polarity). 24/36V controllers:  Active low inputs < 2.6V, active high inputs > Vb – 2.6 V 36/48V controllers:  Active low inputs < 2.9V, active high inputs > Vb – 2.9 V 72/80V controllers:  Active low inputs < 4.4V, active high inputs > Vb – 4.4 V |
| --- | --- |
| Analog inputs: | 2 general purpose inputs which can be used for 2-wire potentiometers, or as supplies for the 3-wire potentiometer wiper inputs.  Motor thermistor input  All analog inputs can also be used as digital inputs. |
| Potentiometer wiper inputs: | Two 3-wire protected inputs. |
| Inductive drive  outputs:  (DO NOT USE  WITH CAPACITIVE LOADS). | 3 configurable PWM outputs. Use in voltage or current control mode.  Voltage-controlled:  Continuous sink current = 2A  Peak current limited to < 2.5A  Open-circuit detection (Iout < 0.1 A) is a configurable option Short-circuit detection (Iout >0.2 A) when drive is in “off” state Voltage-controlled (PWM) mode allows contactors with a rating less than Vnom to be used (range 24 V to Vnom). Current-controlled:  Current output configurable between 0 and 2A |
| Motor speed sensor  inputs: | Quadrature AB encoder signal inputs provided for control of induction motors  UWV digital position sensor or sin-cos analogue position sensor inputs provided for control of permanent magnet motors |

Isolation

| Any terminal to the case: | Withstands 2 kV d.c.  Meets EN1175-1:1998 and ISO3691  Complies with IEC-60664 |
| --- | --- |

4-4

**Specification**

EMC

| Radiated emissions: | EN12895 (Industrial Trucks – Electromagnetic Compatibility) EN 55022:1998, 6, class B  EN 12895:2000, 4.1 Emissions. When part of a system with a motor operating,  FCC Part 15, Radiated Emissions. Meets the standards given in FCC Part 15, Section 15.109: |
| --- | --- |
| Conducted emissions: | No mains port, therefore not required |
| Susceptibility: | Performance level A (no degradation of performance) or level B (degradation of performance which is self-recoverable) subject to the additional requirement that the disturbances produced do not:  ∙ affect the driver‟s direct control of the truck  ∙ affect the performance of safety related parts of the truck or system  ∙ produce any incorrect signal that may cause the driver to perform hazardous operations  ∙ cause speed changes outside limits specified in the standard ∙ cause a change of operating state  ∙ cause a change of stored data |
| Radiated RF field: | EN 61000-4-3, 5.1 Test Level: user-defined test level of 12 V/m EN 12895:2000, 4.2 Immunity  EN 61000-4-6, Table 1 - Test Levels |
| Electrical fast  transient: | EN 61000-4-4, Table 1 - Test Levels, Level 2 |
| Electrostatic discharge: | EN 12895:2000, 4.2 Electrostatic Discharge  4 kV contact discharge  8 kV air discharge |
| Electrical surge: | EN 61000-4-5:1995, Table A.1 – Selection of Test Levels, Class 3 |

Regulatory compliance

| Designed to meet: | EN1175-1:1998 (which covers EN1726 for the controller) ISO 3691  UL583  ASME/ANSI B56.1:1993 |
| --- | --- |

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**Mechanical**

Operating environment

| Operating temperature: | -30°C to +25°C (no current or time derating)  +25°C to +80°C (no current derating, but reduced time at rated operating point)  +80°C to +90°C and -40°C to -30°C (with derating) |
| --- | --- |
| Non-operation  temperature: | -40°C to +85°C (can be stored for up to 12 months in this ambient range) |
| Humidity: | 95% at 40°C and 3% at 40°C |
| Ingress of dust and  water: | IP66 rated (IP54 when 35-way connector unmated – size 2 models only) |

Shock and vibration

| Thermal shock: | EN60068-2-14, Test Na |
| --- | --- |
| Repetitive shock: | 50 g peak 3 orthogonal axes, 3+ and 3– in each axis, 11 ms pulse width |
| Drop test: | BS EN 60068-2-32:1993 Test Ed: Free fall, appendix B, Table 1 |
| Bump: | 40 g peak, 6 ms, 1000 bumps in each direction repetition rate 1 to 3 Hz. |
| Vibration: | 3 g, 5 Hz to 500 Hz |
| Random vibration: | 20 Hz to 500 Hz, acceleration spectral density 0.05 g2/Hz (equivalent to 4.9 grms) |

Weight

|  | **Controller weight** |
| --- | --- |
| Case size 2: | 1.3kg |
| Case size 4: | 2.7kg |
| Case size 6: | 4.6kg |

4-6

Dimensions Size 2 models

Size 4 models

**Specification**

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Size 6 models4-8

**Chapter 5:**

**System design**

**Sizing a motor**

Information required about the application

To select an appropriate induction motor for an application find or estimate the following information: ∙ Minimum battery voltage

∙ Maximum motor speed required

∙ Peak torque required at base speed

∙ Peak torque required at maximum motor speed

∙ Continuous (average) motor power output required to perform the work cycle ∙ Peak motor power output required and duration

Include inertia and friction contributed by the motor, as well as any gearing in the drive chain, when calculating torque and load requirements. If replacing a DC motor with an AC motor in an existing application, the DC motor torque vs. speed curve is a good starting point to determine the required ratings.

Motor maximum speed

Determine the maximum motor speed using the required vehicle or pump maximum speeds and the ratio of any gear box or chain between the motor and the load. Most motor manufacturer rate induction motors at synchronous speed which is 1,500 and 1,800 rpm for a 4-pole motor when operated from 50 Hz and 60 Hz line frequencies respectively.

The maximum speed an induction motor can be used at is determined by the limit of the mechanical speed, typically 4,000 to 6,000 rpm, and the reduction in useful torque at higher speeds. Increasing losses in the iron of the motor at higher speeds may further limit the maximum speed. Always check the maximum speed with the motor manufacturer. Check also any limitations imposed by the maximum frequency of the encoder input signal (see „Motor speed sensor (encoder)‟ on page 5-10).

Torque required between zero and base speed

Calculate the torque required by the application. Use figures for the work that needs to be done against friction and gravity, plus those required to accelerate the load inertia and momentum. Up to rated speed the peak torque that can be supplied when using a correctly specified Gen4 is equal to the breakdown torque. Select a motor with a breakdown torque rating greater than the peak torque required.

5-2

**System design**

Torque required at maximum speed

Calculate the torque as above. As speed increases beyond base speed the maximum torque an induction motor can supply falls as defined by the following two equations:

In the constant power region;

*T*

=

⎜⎜⎝⎛

*T*

max

ω

ω

*rated*

⎟⎟⎠⎞

In the high speed region;

*T*

=

⎜⎜⎝⎛

*T*

max

ω

ω

*rated*

⎟⎟⎠⎞

2

This is shown in Figure 12. Select a motor with a torque rating greater than the peak torque required.

Torque speed curve for a typical induction motor

3.5

3

constant power region high speed region

2.5

) u

p

(

e

u

q

r

o

T

2

1.5

1

0.5

0

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 Speed (pu)

breakdown torque rated torque

Figure 12 Torque speed curve

Continuous power rating

The required continuous power rating of the motor is governed by the application load cycle over a shift. Use the maximum RMS current over a period of one hour to determine the motor rating required. The motor manufacturer will typically specify a 1 hour or continuous rating. Select a motor whose ratings are equal to or greater than your calculated load over 1 hour.

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Peak power rating

The peak power rating required for the application is actually determined by the peak torque required, as this determines the motor current required. Motor manufacturers will provide S1, S2 or S3 duty cycle ratings for the motors.

**Selecting the Gen4 model**

Matching motor and controller ratings is not an exact exercise and therefore you may need to perform iterative calculations. The main considerations when choosing an appropriate Gen4 controller are described below.

Current and power ratings considerations

Consider the following when choosing the appropriate Gen4 controller:

∙ Ensure the controller chosen matches or exceeds the peak current and average current requirements of the motor(s) in the application.

∙ Ensure the application can dissipate the waste heat generated by the controller. If the controller gets too hot it reduces its output, limiting vehicle performance.

Power output restrictions at motor and drive operating temperature limits

A controller protects itself by reducing the current and hence torque available when its temperature limit is reached (Figure 13).

**Gen4 Cutback Curve**

120

100

)

m

u

m

i

x

a

m

f

o

%

(

d

e

w

80 60 40

70 75 80 85 90 9 5 100 Current allo

20

0

Base temperature (°C)

Figure 13 Current allowed vs. controller base temperature

5-4

Circuit configuration

**System design**

Once motor size is determined the application circuit configuration can be defined. A basic single traction configuration (Figure 14) is provided as a starting point for new designs. Given the flexibility of the I/O it is possible to configure a wide range of systems. Refer to „Signal connections‟ on page 3-11 to see what each I/O signal is capable of doing as you design your system. For pump applications a basic single pump system is shown in Figure 15.

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Single traction wiring diagram

Figure 14 Single traction wiring diagram

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**System design**

Single pump wiring diagram

Figure 15 Stand-alone pump wiring diagram

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**Twin motor systems**

A twin motor system may be powered by two Gen4 controllers operating in master–slave configuration. In this case the necessary commands are transmitted by the master node to the slave node via the CANbus.

Motors may be operated independently in a combined traction-pump application or operated in tandem where each motor drives a separate wheel. In this latter case the controller (where there are two controllers, the controller configured as master):

∙ Assists in the steering of a vehicle by adjusting the torque of each motor dependent on the steering angle.

∙ Reverses the direction of the inner wheel in order to provide a smaller turning circle. The speed of the outer wheel is also limited during a turn.

An example of possible wiring for Gen4 traction controllers operating in master-slave configuration is shown in Figure 16.

**Auxiliary components**

Main contactor

Select the appropriate contactor line contactor from Table 5. A line contactor used at its rated coil voltage must be rated „continuous‟. Contactor coil voltage chopping allows the use of coils rated „intermittent‟, provided the manufacturer‟s conditions are met.

**Gen4 peak output current**

**Coil Sevcon P/N**

**Manufacturer Notes**

Up to 450 A 24 V 828/37024 Albright SW200-29 See paragraph below 48 V 828/57026 Albright SW200-20

80 V 828/67010 Albright SW200-460

Up to 650 A 24 V 828/39001 Albright SW200 Chop at 17 V (intermittent coil) Table 5 Main contactor rating

The controller can drive any contactor with coil voltages from 12 V to Vb. It is worth considering the use of 24 V contactors with the contactor drive output set to voltage-control mode. This allows you to use one type of contactor for any battery voltage (24 V to 80 V). Pull-in voltage, pull-in time and hold-in voltage values are all configurable.

Contactor coils must not be wired to the supply side of the key switch. Use the Output 1 Supply / Output 2 Supply / Output 3 Supply pins provided (see Table 2).

35 Way AMPSeal Connector Kit

Kit consists of Gen4 mating 35 way AMPSeal connector and pins, Sevcon p/n 661/27901 Emergency stop switch

Refer to the appropriate truck standards.

On-board fuse

See „On-board fuse mounting‟ on page 3-8.

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**System design**

****

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Figure 16 Dual traction wiring diagram

Key switch fuse F2

Use a fuse rated for the larger of: A) the sum of the drive currents plus 1A for internal circuits, and B) the capacitor pre-charge circuit. In the following example there are two contactors each drawing 2 A:

|  | **Device** | **Current** |
| --- | --- | --- |
| A | Line contactor | 2 A |
| Pump contactor | 2 A |
| Gen4 control circuits | 1 A |
| B | Pre-charge circuit | 7 A |

Fuse choice: 7A.

Motor speed sensor (encoder)

A 4-wire connection is provided for open-collector or current-source quadrature pulse encoder devices (software configurable). These types of encoder are optimized for accurate speed measurement, required for efficient control of induction motors.

AB Quadrature Pulse Encoder (pin numbering may vary)

12

26 14

Gen4 Controller

+5/10V Supply

encoder A

E

34

25 15

encoder B 0 V

Figure 17 - Sample wiring for an AB quadrature speed encoder

You can use the following types of encoder, or equivalents:

| **Type** | **Output** | **Supply** | **Specification** |
| --- | --- | --- | --- |
| Bearing Type  (SKF and FAG) | Open collector | 5 to 24 V DC | 64 and 80 pulses per revolution  Dual quadrature outputs  Output low = 0 V (nominal) |
| HED Type  (Thalheim) | Constant current | 10 V nominal | 80 pulses per revolution  Dual quadrature outputs  Output low = 7 mA  Output high = 14 mA |

The number of encoder pulses per revolutions (**n**) and the maximum motor speed (**N**) are related to, and limited by, the maximum frequency of the encoder signal (**f**max). The following table shows the maximum motor speed for a given encoder on a 4-pole motor.

| **Encoder**  **ppr** | **Maximum motor speed (rpm)** |
| --- | --- |
| 128 | 6000 |
| 80 | 10000 |

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**System design**

| 64 | 10000 |
| --- | --- |

For other types of encoder and motor use the formulae:

( ) max*n perrevolution N rpm f Hz*×

( ) ( ) =

60

with **f**max limited to 13.3 kHz.

and

( ) max*prpm N rpm* =

20000( )

( / 2)

Encoder PPR is set at 6090h. Additional encoder configuration (pull-up, supply, etc) is set at 4630h. Motor commutation sensor

UVW Commutation Sensors

Commutation sensors are designed to measure the position of the rotor shaft within the motor, rather than its rotational speed. Rotor position information is used for control of permanent magnet motors, as it allows the controller to energise the motor phases appropriately based on the measured position of the magnets on the rotor.

The Gen4 controller provides inputs for both digital UVW style position sensors and analogue sin-cos sensors. Either of these can be used for control of permanent magnet motors.

UVW Position

Encoder (pin numbering may vary)

12

26 5

Gen4 Controller +5/10V Supply

3 17 channel U E

45

29 15

channel V channel W 0 V

Figure 18 - Sample wiring for a UVW commutation sensor

3 digital inputs are provided for UVW encoders. The encoder should provide one pulse on each channel per electrical cycle of the motor, and each pulse should be 120° out of phase with the others and have a 50% duty cycle:

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Figure 19 - Example pulse train from a UVW commutation sensor

Sin-Cos Commutation Sensor

Analogue sin-cos encoders should provide one sine wave and one cosine wave per mechanical rotation of the motor. Peak and trough signal voltages must have a minimum of 1V difference.



Figure 20 - Example of signals from a sin-cos position sensor

Sin-cos Position Encoder (pin numbering may vary)

12

26 21

Gen4 Controller

+5V Supply

Sin input

E

34

35 15

Cos input 0 V

Figure 21 - Sample wiring for a sin-cos commutation sensor5-12

**System design**

Sin-cos encoders are typically powered by a 5V supply. Therefore it is important to ensure that the controller is configured to supply 5V on pin 26. This should be done by setting the encoder configuration object dictionary entry at 4630h.

The standard Gen4 build does not provide inputs for the sin and cos signals. Therefore, if operation with a sin-cos analogue encoder is required then this must be specified as a hardware build option. Controllers built for use with sin-cos encoders have the functions of pins 31 and 35 reassigned from digital and analogue inputs to sin and cos signal inputs respectively. Please contact your local dealer for more information on the sin-cos encoder build option.

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**Initial power up sequence**

**Incorrectly wired or configured vehicles may behave in unexpected ways. At the end of the following procedure, only lower the drive wheels to the ground after correct operation of the motor and encoder has been confirmed.** 

Checks prior to power up

Follow this checklist prior to applying power to your system:

∙ Jack up the vehicle so that the drive wheels are clear of the ground.

∙ Confirm all connections are tightened to specified level.

∙ Ensure all plugs are fully inserted.

∙ Confirm power wiring connections are made to the correct terminals

(B+, B-, +, M1, M2 and M3).

∙ Ensure the controller is securely mounted (from a mechanical and thermal perspective). ∙ Ensure there is adequate and correctly ducted airflow for the fan cooled version.

∙ Check the routing of cables is safe with no risk of short circuit, overheating or cable insulation wear due to rubbing.

Checks after power is applied

Apply power and do the following:

∙ Use DriveWizard (see page 6-2) or any configuration tool to complete the configuration process which starts on page 6-7.

∙ Using the drive controls ensure the wheels rotate in the expected direction. If they do not, check the motor wiring, encoder wiring and encoder configuration (page 6-12).

It should now be safe to lower the vehicle to the ground and test drive. Proceed with caution.5-14

**Chapter 6:**

**Configuration**

**Introduction**

This section covers what you need to do to configure Gen4‟s software once you have designed and installed your hardware. All of Gen4‟s parameters have a default value and the amount of configuration needed is dependent on your particular system.

The main topics are:

∙ DriveWizard configuration tool: installation and use

∙ CANopen: an introduction to the protocol and its use in Sevcon products

∙ An overview of the configuration process outlining what needs to be done and the order in which it must be done

∙ The configuration steps

**DriveWizard configuration tool**

DriveWizard (Figure 22) is Sevcon‟s proprietary configuration tool. It allows the user, subject to a secure login process, to monitor, configure and duplicate the parameters of any Sevcon CANopen node such as the Gen4 controller. DriveWizard can also be used to monitor and configure the parameters of any 3rd party CANopen node. The information presented here is an overview only. For more information see DriveWizard‟s on-screen help system.



Figure 22 DriveWizard and hardware

DriveWizard functionality with lowest access level

The lowest access level allows you to review or monitor:

∙ DCF files on disk

∙ the contents of the Object Dictionary (applies also to 3rd party nodes)

∙ the mapping of CANopen PDO communication objects

∙ system logs

∙ fault logs

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**Configuration**

∙ counters

∙ operational logs

∙ real time data (applies also to 3rd party nodes).

You can also change the baud rate and Node ID of a connected node. To write information to a Sevcon CANopen node you will need a higher level of access.

Status bars

User controls are invisible when DriveWizard is busy reading/writing.

User prompts are displayed in the top left of the screen as shown below:



The bottom right area of the status bar shows what DriveWizard is doing if busy and sometimes the result of DriveWizard‟s action if this is not clear from the main display area.



The bottom left status bar in the above example shows how many CAN nodes are connected and the access level of the person using DriveWizard.

When viewing the Object Dictionary in DriveWizard, parameters are color coded and the key is shown in the lower portion of the screen.

Saving, duplicating and restoring a node’s configuration You can use DriveWizard to:

∙ Save a node‟s configuration. This can be used at some later date to clone the node‟s configuration. ∙ Duplicate a node‟s configuration, in real time, to another node on the CANbus. ∙ Restore a configuration to a node.

Data monitoring

You can use DriveWizard to monitor data or parameters of a Sevcon or 3rd party node in real time.

**CANopen**

This section assumes you have an understanding of CAN and are familiar with its use. If you are new to CAN or CANopen please refer to the CiA (CAN in Automation) website, www.can-cia.org for further information.

The following information provides an introduction to the important CANopen terminology used in this manual and how it relates to the configuration of your Gen4 controller.

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CANopen protocol

CANopen is a CAN higher layer protocol and is defined in the DS301 „Application Layer and Communication Profile‟ specification. All CANopen devices must adhere to this standard. To provide greater standardization and interoperability with 3rd party devices, Gen4 is designed to use the CANopen protocol for communication on its CANbus and meets V4.02 of DS301.

CANopen also supports standardized profiles, which extend the functionality of a device. The controller supports the following CANopen standardized profiles:

∙ DS401 (V2.1) – Device Profile for Generic I/O Modules

∙ DSP402 (V2.X) – Device Profile for Drives and Motion Control

Object Dictionary

Any device connected to the CANopen network is entirely described by its Object Dictionary. The Object Dictionary defines the interface to a device. You setup, configure and monitor your Gen4 controller by reading and writing values in its Object Dictionary, using a configuration tool such as Sevcon‟s DriveWizard (see page 6-2).

There are two important text files associated with the Object Dictionary. These are: EDS (electronic data sheet)

An EDS is a text file representation of the Object Dictionary structure only. It contains no data values. The EDS is used by configuration software such as Sevcon‟s DriveWizard to describe the structure of a node‟s Object Dictionary. An EDS for each Gen4 model and software version, is available from Sevcon. The EDS file format is described in the DSP306 – Electronic Data Sheet Specification.

*Each Object Dictionary matches a particular Gen4 software revision, and its structure is hard coded into the controller software.* 

DCF (Device Configuration File)

This is a text file similar to an EDS except that it contains data values as well as the Object Dictionary structure.

DCFs are used to:

∙ Download a complete pre-defined configuration to a node‟s Object Dictionary. ∙ Save the current configuration of a node‟s Object Dictionary for future use.

Communication objects

These are SDO (service data object) and PDO (process data object) as described below. There is a third object, VPDO (virtual PDO), used by Gen4 which is not a CANopen object. It is described here because its function is important and similar to that of a PDO.

SDO (Service Data Object)

SDOs allow access to a single entry in the Object Dictionary, specified by index and sub-index. They use the client–server communication model, where the client accesses the data and the server owns the target Object Dictionary.

SDOs are typically used for device configuration (e.g. via DriveWizard) or for accessing data at a very low rate.

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PDO (Process Data Object)

**Configuration**

PDOs are used by connected nodes (for example in a twin motor configuration) to exchange real time data during operation. PDOs allow up to 8 bytes of data to be transmitted in one CAN message.

They use the producer-consumer communication model, where one node (the producer) creates and transmits the PDO for any connected nodes (consumers) to receive. Transmitted PDOs are referred to as TPDOs and received PDOs as referred to as RPDOs.

VPDO (Virtual Process Data Object)

VPDOs do a similar job as PDOs for data exchange, but internal to a single Sevcon node. They are unique to Sevcon and are not part of CANopen.

Network Configuration

*The easiest way to configure a CANopen network is to use the auto-configuration feature. See section, Automatic Configuration Mapping (page 6-12) for more information.* 

General

If auto-configuration cannot be used or if additional, non-Sevcon nodes need to be added, use the following procedure to setup the network:

1. Set node ID and baudrate in 5900h to the required values. Node IDs must be unique, and the baudrate must be the same for each node.

2. Set SYNC COB-ID in 1005h to 0x40000080 for the master node, or to 0x00000080 for all slave nodes. Bit 30 is set to indicate to a node if it is the SYNC producer. Only one node in the network should be configured as the SYNC producer. This should normally be the master. On the SYNC producer, set the SYNC rate in 1006h.

3. Set the EMCY message COB-ID to 0x80 + node ID in 1014h.

**EMCY COB-IDs must be configured correctly to ensure the master handles EMCYs from slaves correctly.**

4. Configure the heartbeat producer rate in 1017h. This is the rate at which this node will transmit heartbeat messages.

5. Configure the heartbeat consumer rate in 1016h. A consumer should be configured for each node to be monitored.

**Heartbeats must be configured correctly for correct network error handling. The master node should monitor heartbeats from all slave nodes. Slave nodes should, at a minimum, monitor heartbeats from the master node.** 

**Loss of CANbus communication from any one node must cause a heartbeat fault to occur.**

6. On standalone systems with non-CANopen nodes attached, hardware CANbus fault detection should be enabled at 5901h. CANbus fault detection is automatically enabled for multi-node CANopen systems.

7. Configure additional SDO servers. An SDO server allows another CANopen device to SDO read/write from a node‟s object dictionary. Each node has one default SDO server (1200h) which is reserved for communication with configuration tools like DriveWizard or the

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calibrator. Another 3 SDO servers can be configured at 1201h to 1203h. These should be used as follows:

a. On slave nodes, configure a server to allow the master node to communicate. b. If there is a display in the system, configure a server to allow the display access.

8. On the master node, configure SDO clients at 1280h to 1286h. There must be one client for each slave node. The SDO clients must be configured to match the corresponding SDO server on each slave.

9. On the master node, list all slave node IDs at 2810h.

10. Configure RPDOs (1400h to 17FFh) and TPDOs (1800h to 1BFFh) appropriately for the system. See section, Manual object mapping (page 6-10), for more information.

11. Configure the RPDO timeout function if required. See section PDO mapping (page 6-11) for more information.

3rd Party CANopen Devices

At power up, the Gen4 master will communicate with all slave nodes to identify which nodes are Sevcon devices and which are not using the vendor ID in 1018h. This instructs the Gen4 how to handle EMCY messages from each node.

Gen4 knows how to react to EMCYs (faults) from Sevcon slaves and can take appropriate action. Gen4 does not know how to react to EMCYs from 3rd party devices, so the required fault reaction to 3rd party device EMCYs must be set at 2830h.

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**Configuration**

**Configuration process overview**

**Electric vehicles can be dangerous. All testing, fault-finding and adjustment should be carried out by competent personnel. The drive wheels should be off the floor and free to rotate during the following procedures.** 

*We recommend saving parameter values by creating a DCF, before making any alterations so you can refer to, or restore the default values if necessary. Do this using DriveWizard.* 

This part of the manual assumes you have a vehicle designed and correctly wired up with a CANopen network setup. Before you can safely drive your vehicle it is necessary to go through the following process in the order presented:

| **Step** | **Stage** | **Page** |
| --- | --- | --- |
| 1 | Motor characterization | 6-8 |
| 2 | I/O configuration | 6-9 |
| 3 | Vehicle performance configuration | 6-17 |
| 4 | Vehicle features and functions | 6-32 |

Access authorization

To prevent unauthorized changes to the controller configuration there are 5 levels of accessibility: (1) User, (2) Service Engineer, (3) Dealer, (4) OEM Engineering and (5) Sevcon Engineering. The lowest level is (1), allowing read only access, and the highest level is (5) allowing authorization to change any parameter.

To login with DriveWizard, select User ID and password when prompted.

To login with other configuration tools write your password and, optionally, a user ID to object 5000h sub-indices 2 and 3. The access level can be read back from sub-index 1. The password is verified by an encryption algorithm which is a function of the password, user ID and password key (5001h).

The password key allows passwords to be made unique for different customers. The user ID also allows passwords to be made unique for individuals.

How NMT state affects access to parameters

Some important objects can only be written to when the controller is in the pre-operational state. DriveWizard takes Gen4 in and out of this state as required.

If you are not using DriveWizard you may need to request the CANopen network to enter pre operational before all objects can be written to.

To enter pre-operational, write „1‟ to 2800h on the master node.

To restore the CANopen network to operational, write „0‟ to 2800h.

The controller may refuse to enter pre-operational if part of the system is active: for example, if the vehicle is being driven. The request is logged in the EEPROM however, so if power is recycled the system won‟t enter operational and remains in pre-operational after powering up.

The NMT state can be read at 5110h where 05 = operational and 7F = pre-operational.

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**Motor characterization**

Ensure you have completed the CANopen network setup process.

Determining motor parameters

To provide optimum motor performance Gen4 needs the basic motor information normally found on the name plate as well as the following information:

∙ A value for each of the electrical parameters of the induction motor as shown in Figure 23. ∙ The magnetic saturation characteristics of the motor in the constant power and high speed regions. ∙ Current and speed control gains.



Figure 23 AC motor single-phase equivalent circuit

To determine these parameters use one of the following methods:

1. Ask the motor manufacturer to provide the data and enter it in the Object Dictionary at 4640h and 4641h. Also enter encoder data at 4630h and 6090h and motor maps at 4610h to 4613h. 2. Use the motor name plate data and the self characterization routine provided by Gen4 and DriveWizard (described below).

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Self characterization

**Configuration**

**The self characterization function will cause the motor to operate. Ensure the vehicle is jacked up, with the driving wheels off the ground and free to turn, before starting the test.** 

The motor self-characterisation process allows a user to determine the electrical parameters required for efficient control of AC induction motors using a Gen4 controller connected to a PC or laptop running characterisation software. For further information, please contact your local Sevcon representative.



**I/O configuration**

Ensure you have completed the CANopen network setup and Motor Characterization processes described above.

The individual characteristics and mapping of the I/O in your application need to be setup. This can be done manually, or one of a selection of predefined setups can be selected. Predefines setups exist for many of the common vehicle functions such as standalone traction, standalone pump and twin traction.

For manual configuration, it is necessary to use PDOs and VPDOs to map application objects on the master node (2000h to 24FFh) to the hardware I/O objects on all other nodes (6800h to 6FFFh). Auto configurations will create the required PDO and VPDO mappings depending on which pre-defined I/O configuration has been selected, but additional PDO mappings can be added if desired.

To configure I/O:

∙ **Either** configure PDOs and VPDOs to map application objects on the vehicle master node to hardware I/O objects on other nodes, **or** select a pre-defined configuration and use auto configuration to set up PDOs and VPDOs

∙ Setup each hardware I/O object, including wire-off protection.

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Manual object mapping

To enable the controller to perform the functions required in your system it is necessary to map object to object (e.g. a measured input signal mapped to a steer operation).

This is achieved by setting up PDOs (node to node mapping) and VPDOs (internal mapping on each controller) as described below.

Apply mapping to Gen4 as follows:

∙ Standalone controllers: setup VPDOs only

∙ Networked controllers: setup VPDOs and PDOs

*Before starting the mapping process it is a good idea to draw out a map of what you want to do. The amount of mapping required depends on the electrical wiring of your vehicle. Check to see if the default settings satisfy your needs before making changes.* 

VPDO mapping

VPDO mapping is defined by objects in the range 3000h to 3FFFh as shown in the table below. Use DriveWizard, or any other configuration tool, to access these objects.

| **Feature** | **Object**  **indices** | **Notes** |
| --- | --- | --- |
| Motor | 3000h | Used to map the master to the type of local motor |
| Input mapping | 3300h | Used to map digital input signals to application inputs |
| 3400h | Used to map analog input signals to application inputs |
| Output mapping | 3100h | Used to map application outputs to digital output signals |
| 3200h | Used to map application outputs to analog output signals |

To help understand how to map internal objects an example VPDO mapping is shown in Figure 24. A digital switch input is mapped to the seat switch function to control the traction application, i.e. with no seat switch input the vehicle is prevented from moving.

6-10

Master

traction

application

local

I/O

seat

switch

digital inputs

2124h

(seat switch)

3300h

(VPDO mapping) Object Dictionary

6800h [1]

(digital inputs 1-8)

VPDO

manager

**Configuration**

Figure 24 Example of a digital input mapped to the seat switch via VPDO

The number of sub-indices of each VPDO object depends on the amount of I/O on the device. For example, 3300h has 14 sub-indices on a device with 8 digital inputs and 5 analog inputs. Sub-index 0 gives the number of I/O channels in use. In 3300h sub-indices 1 to 8 correspond to the digital inputs and sub-indices 9 to 14 correspond to the digital state of analog inputs.

To map the local I/O to an application signal object, set the appropriate VPDO sub-index to the application signal object index. If the seat switch shown in the above diagram was connected to digital input 4 (bit 3 in 6800h,1), sub-index 4 of 3300h would be set to 2124h.

Some further examples are:

∙ Map FS1 to read the value of digital input 8 (connector A, pin 11): at 3300h sub-index 8 enter the value 2123h.

∙ Map the electromechanical brake signal to be applied to analog output 2 (customer connector, pin 7): at 3200h sub-index 2 enter the value 2420h.

The data flow direction between the application signal objects and the local I/O objects depends on whether they are inputs or outputs. For inputs, the flow is from the local I/O to application objects, and vice versa for outputs.

Motor VPDOs are slightly different. There are six parameters for each motor, some of which flow from application to local I/O (controlword, target torque and target velocity) and some of which flow from local I/O to application (statusword, actual torque and actual velocity).

PDO mapping

The controller supports 5 RPDOs (receive PDOs) and 5 TPDOs (transmit PDOs). Up to 8 Object Dictionary entries can be mapped to each PDO. Every PDO must have a unique identifier (COB-ID).

Setup RPDOs and TPDOs to transmit and receive events between nodes, and map I/O from one node to applications in another node.

The easiest way to do this is using DriveWizard. If you are using a 3rd party configuration tool, the relevant Object Dictionary indices are listed in Table 6.

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| **Feature** | **Object**  **indices** | **Notes** |
| --- | --- | --- |
| Input mapping | 1400h-15FFh | RPDO communication parameters |
| 1600h-17FFh | RPDO mapping |
| Output mapping | 1800h-19FFh | TPDO communication parameters |
| 1A00h-1BFFh | TPDO mapping |

Table 6 Objects associated with mapping

An example mapping (Figure 25) shows the movement of PDOs in a master-slave configuration in which a digital input to the slave has been mapped to the seat switch object in the master.

Master

traction

application

seat

switch

1600 - 8h

(RPDO mapping)

2124h

(seat switch)

PDO

n

PDO

n

1A00 - 8h

(TPDO mapping)

Slave

Object Dictionary

e

po

N

AC

e

po

N

AC

Object Dictionary

digital

6800h [1]

(digital inputs 1-8)

inputs

local I/O

*(consumer) (producer)*

CANbus

Figure 25 Example of a digital input mapped to the seat switch object via PDO and the CANbus

Gen4 supports RPDO timeout fault detection. This can set a warning, drive inhibit or severe fault depending on the configuration in 5902h.

*RPDO timeout can be used for non-CANopen systems which do not support heartbeating. By default, RPDO timeout is disabled, and normal CANopen heartbeating protocol (see section Network Configuration (page 6-5)) is assumed to be used.* 

Automatic Configuration Mapping

The auto-configuration feature allows the user to select their vehicle I/O from a list of pre-defined configurations. The principle is identical to the manual process described above, but the PDO and VPDO mappings are created by each controller automatically at start up as well as CANopen network configuration settings. This feature provides an easy and reliable method of setting up both single and

6-12

**Configuration**

multi node systems, providing they match one of a selection of pre-defined setups (refer to page 1 for details on the available configurations).

To enable auto configuration on all nodes set 5810h sub-index 1 to 0CFFh (This corresponds to “Enabled”/”Both VPDO and PDO” for all IO auto configuration options in Drive Wizard). This enables the auto configuration of local and remote (via CANopen) analogue IO, digital IO and motor control. This is the default state for automatic configuration. It is possible to disable individual parts of the configuration to allow for user customization via the methods described above.

Digital input, analogue input and analogue output configurations can be selected from the predefined tables and their numbers entered into sub-indices 3, 5 and 6. This need only be set on the master controller if a multimode system is being configured.

CAN node function and configuration can also be defined via the auto configure feature. For each node the following should be specified:

∙ If it is Master or Slave in the CANBus system

∙ On the Master node, specify it‟s function, e.g. Traction, right side controller and also which other nodes are present as slaves, e.g. Pump, Power steer.

∙ On the Slave node, simply specify that it is a slave and which type of slave it is, e.g. Pump. Figure 26 - DriveWizard screen showing automatic object mapping

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Encoder

**It is important that the number of encoder pulses per revolution is entered correctly. If this information is not correct, the controller may not be able to brake the motor effectively.** 

To configure the encoder:

1. Enter the resolution pulses/rev at 6090h.

2. Check whether the encoder requires controller pull ups enabled (e.g. open-collector type) and enable pull-ups if needed at 4630h. The default setting is no pull-ups, which is suitable for current source encoder types.

3. Select the required encoder supply voltage (10V or 5V) at 4630h.

To change the encoder polarity (if required) change the setting at 607Eh (reverses the forward and reverse speed measurements).

Digital inputs

The state of the digital inputs can be read at object 6800h.

*Digital inputs are either all active low (switch return to battery negative) or all active high (switch return to battery positive). A mixture of active low and active high inputs is not possible. The default setting is active low.* 

To configure digital inputs:

∙ Set active high/low logic at 4680h.

∙ Set wire off protection at 4681h. Any two digital inputs can be configured with wire-off protection. See Table 2 Connector A pin out and wiring information on page 3-15 (pins 14 and 15) for more details.

∙ Set digital input polarity at 6802h. This is used to configure normally closed/open switches. Analog inputs

The analog input voltages can be read at object 6C01h. Voltages are 16-bit integer values with a resolution of 1/256 V/bit.

Although each input is usually assigned a specific task by default, any of the inputs can accept a variable voltage or a potentiometer. Analog inputs can also be used as additional digital inputs.

The following table summarises the analog inputs and any special features:

| **Name** | **Object** | **Pin** | **Usage** |
| --- | --- | --- | --- |
| Wiper Input 1 | 6c01h,1 | 22 | Input from external voltage source or 3-wire pot wiper. Use pin 34 as supply for 3-wire pot. |
| Wiper Input 2 | 6c01h,2 | 23 | Input from external voltage source or 3-wire pot wiper. Use pin 35 as supply for 3-wire pot. |
| Analog Input 1 or  Supply for Wiper Input 1 | 6c01h,3 | 34 | Use for 2-wire pot input or as a supply for wiper input 1. Has internal pull-up. |
| Analog Input 2 or  Supply for Wiper Input 2 | 6c01h,4 | 35 | Use for 2-wire pot input or as a supply for wiper input 2. Has internal pull-up. |
| Motor thermistor | 6c01h,5 | 33 | Use for motor thermistor input or 2-wire pot input. |

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**Configuration**

|  |  |  | Has internal pull-up. |
| --- | --- | --- | --- |

Wire-off detection

Enable wire-off detection at 46C0h to 46C4h. For each input specify the allowable range of input voltages. To disable, set the ranges to maximum.

Motor thermistor input

You can connect a thermistor sensor to the Motor thermistor input or a switch to any digital input.

| **Type** | **Specification** |
| --- | --- |
| PTC Silistor | Philips KTY84 or equivalent |
| Switch | Connected to a general purpose digital input |

To setup go to object 4620h:

∙ Configure as none, switch or PTC thermistor

∙ For KTY84 thermistors, set the PTC type to KTY84.

∙ For non-KTY84 PTC thermistors, set the PTC type to User Defined and then set the expected voltages at 100ºC (high temperature voltage) and 0ºC (low temperature voltage). The Gen4 will linearly interpolate temperature with voltage.

∙ If you are using a switch select the digital input source

Read the measured motor temperature (PTC) or switch operation at object 4600h. Analog inputs configured as digital inputs

Each analog input can also be used as a digital input.

To configure an analog input as a digital input, set the high and low trigger voltages at object 4690h.

The digital input status object, 6800h, contains enough sub-indices for the digital and analog inputs. Sub index 1 is the states of the digital inputs, and sub-index 2 is the states of the analog inputs converted to digital states.

Analog (contactor) outputs

There are 3 analog outputs which you may have mapped to one or more contactor functions such as: line contactor, pump, power steer, electro-brake, external LED, alarm buzzer and horn.

Configure each of the outputs used in your system:

∙ Choose voltage control or current control for each analog output at 46A1h.

(At the time of writing, current controlled devices can only be operated from Gen4 by mapping a signal input to the controller from an external 3rd party node).

∙ Set the frequency of each output to a fixed value of 16 kHz or any value between 40 Hz and 1 kHz at 46A2h and 46A3h. You can have only one low frequency setting per controller. Low frequencies are normally used with current-controlled outputs.

∙ Set the analog output values at object 6C11h. The value is either a voltage or current depending on whether the output is voltage controlled or current controlled. Values are 16-bit integers with a resolution of 1/256 V/bit or A/bit.

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Error control

**It is important that analog outputs on nodes other than the master must have appropriate error configuration to protect against CANbus faults. This section explains how to configure the outputs to go to a safe state in the event of a CANbus fault. It is the installers responsibility to define what a safe state is for each output.** 

In a CANopen network, the slave node on which the analog (contactor) outputs reside can be different to the master node which calculates the output value. If the CANbus fails, the master node is no longer able to control the slave outputs. In this situation, the outputs may need to change to a safe value. This is achieved with error control.

To configure error control:

∙ Set each output at object 6C43h to use its last set value or the value at 6C44h if the CANbus fails.

∙ Set values if needed at 6C44h for each output. These values are 32-bit integers, but the the bottom 16-bits are ignored. The top 16-bits give the error value in 1/256 V/bit (or A/bit for current controlled outputs).

Some examples of typical configurations may be:

∙ Electro-mechanical brake on slave node. If CANbus communication is lost, it may be desirable to apply the electro-mechanical brake on the slave device. In this case, enable error control in 6C43h and set the error value in 6C44h to 0.

∙ Power steer contactor on slave node. If CANbus communication is lost, it may be desirable to leave the power steer output in its previous state. In this case, disable error control in 6C43h.

∙ CANbus communication error lamp on slave node. If CANbus communication is lost, it may be desirable to activate an output on the slave device. In this case, enable error control in 6C43h and set the error value in 6C44h to an appropriate voltage for the lamp.

*The above examples are for illustration purposes only. It is the responsilbity of the installer to decide on the required state for each output in the event of a CANbus failure.* 

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