Gen4 size 8

Applications Reference Manual

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SEVCON®

Electrification Partner

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 SAS
Parc d'Activité du Vert Galant Rue
Saint Simon
St Ouen l'Aumône
95041 Cergy Pontoise Cedex
France
Tel +33 (0)1 34 30 35 00
Fax +33 (0)1 34 21 77 02
sales.fr@sevcon.com

Sevcon Japan K.K.
Kansai Office 51-26 Ohyabu Hikone
Shiga Japan 522-0053
Tel +81 (0) 7 49465766
jp.info@sevcon.com

Sevcon Asia Ltd
Room No.202 Dong-Ah Heights
Bldg
449-1 Sang-Dong Wonmi-Gu
Bucheon City Gyeounggi-Do
420-816 Korea
Tel +82 32 215 5070
sales.kr@sevcon.com

Sevcon Germany
Hintere Str.32
73266 Bissingen an der Teck
Germany
Tel: +49 (0)170 9980294
de.info@sevcon.com

www.sevcon.com

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1 Chapter 1: Introduction

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About Gen4 size 8 documentation

This version of the manual

This version of the Gen4 size 8 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

Scope of this manual

The Application Reference Manual provides important information on configuring lift and traction drive systems using Gen4 size 8 controllers as well as details on sizing and selecting system components, options and accessories.

The manual also presents important information about the Gen4 size 8 product range.

Related documents

The following documents are available from Sevcon:

- The Object Dictionary providing important information about CANopen communication with Gen4 size 8.
- Device Configuration Files (DCF) and Electronic Data Sheets (EDS) for each Gen4 size 8 model and revision.

Drawings and units

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

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.

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.

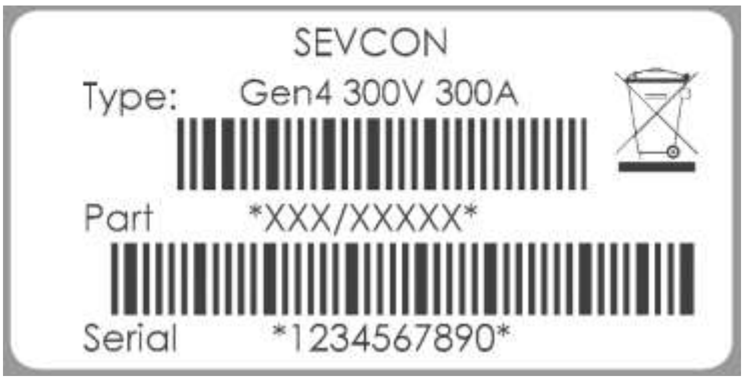

Figure 1 Product identification label

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 centre through the Sevcon website, www.sevcon.com.

Product warranty

Please refer to the terms and conditions of sale or contract under which the Gen4 size 8 was purchased for full details of the applicable warranty.

2 Chapter 2: About the Gen4 size 8

Introduction

Sevcon Gen4 size 8 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 size 8's software functions to suit a wide range of traction and pump applications.

Given Gen4 size 8's mapping versatility it is important to ensure you map your application signals to the correct software functions (see 'Manual object mapping' on page 6-11). 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 size 8 is fully customizable using Sevcon's Calibrator handset or DVT, 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

Intended use of the Gen4 size 8

The Gen4 size 8 motor controller can be used in any of these main applications for traction control:

- Automobiles
- Vans
- Light trucks
- Buses
- Airport ground support (AGS), including tow tractors
- Utility vehicles
- Burden carriers
- Marine

Available accessories

The following accessories are available from Sevcon

- Loose equipment kit (connectors and pins) for Gen4 size 8
- CANopen Calibrator Handset
- DCDC converters
- SmartView™ display

- ClearView™ display
- Hourmeters
- Contactors
- Fuses
- DVT - PC based configuration tool
- SCWiz – PC based motor characterisation tool

Overview of a vehicle drive system

The main components (excluding control inputs such as throttle and seat switch) are shown in Figure 2. In this example there are two traction motors. Communication between the controllers is achieved using the CANopen protocol. This protocol also allows Gen4 size 8 to communicate with Sevcon displays as well as other non-Sevcon, CANopen compliant devices.

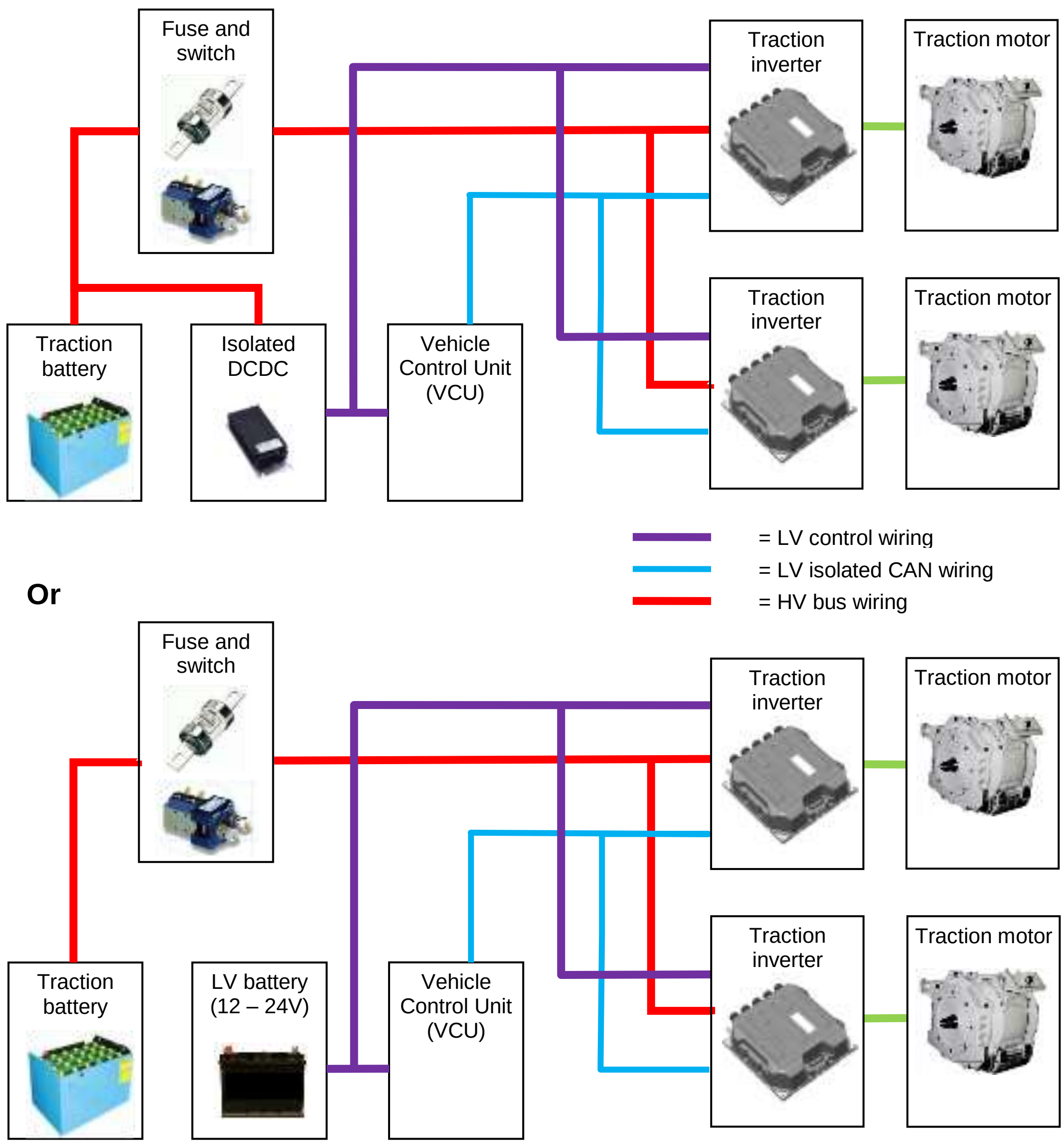

Figure 2 Vehicle system components

A fuse, pre-charge circuit and line contactor must be fitted between the traction battery and the controller power circuits.

Principles of operation

Functional description

The main function of Gen4 size 8 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 i_d and i_q, 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.

Gen4 size 8 electrical block diagram

The electrical circuit blocks present in Gen4 size 8 are shown in Figure 3 and have the following functions:-

- Inverter power stage – this converts the DC battery supply into AC to power the motor. See the following section for more details.
- Gate drives – the low power gate control signal from the control logic is isolated and buffered by these circuits. Output short circuits are also detected by these circuits.
- Current and voltage measurement – these circuits provide an isolated voltage and current measurement for the control logic. Over-current and over-voltage conditions are also detected.
- Control power supplies – these convert a 24V nominal supply into the voltage required for the control logic
- Control logic – software runs on microprocessor and DSP circuits with input and output circuits for analogue and digital inputs, the encoder, CAN bus and analogue outputs.

- Isolation fault detector – An external Isolation Fault Detector must be fitted in high voltage systems. This circuit must detect if the high voltage battery is shorted to the logic circuits.

The high voltage power circuits are fully isolated from the logic control and CAN circuits. All of the required power supplies and control signals for the high voltage system are isolated magnetically or optically from the low voltage system .

All the control inputs and outputs such as the analogue inputs, digital inputs and motor encoder are referenced to the 24V logic circuit ground. The Can bus is isolated from the control circuit ground with an isolation resistance of 1 MegaOhm. A separate CAN ground is made available on the user light wiring connector.

Do not connect the high voltage traction circuit to the 24V logic circuits directly. If you do this the isolation barrier will be bypassed. This could cause high voltages to be present on circuits which do not have enough protection against accidental touch. Protection of logic circuits against accidental shorts to the high voltage battery relies on this isolation barrier. If a wiring fault was present logic circuits could be damaged.

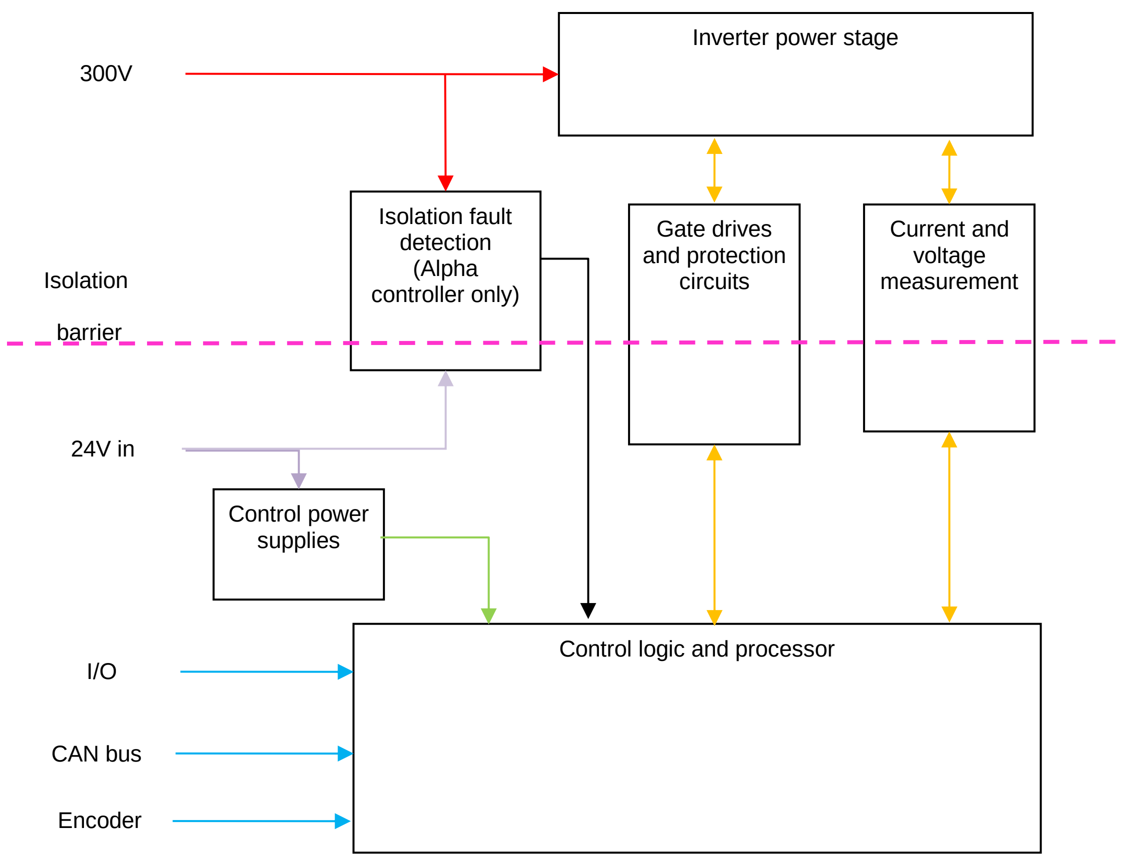

Figure 3 Motor controller electrical block diagram

Power conversion section

The power conversion section of Gen4 size 8 employs a 6-switch IGBT bridge operating at an effective frequency of either 16 kHz or 24kHz (the PWM frequency is set using 5830_h). Excellent electrical and thermal efficiency is achieved by:

- Minimization of thermal resistances.
- Use of the latest IGBT 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.

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 size 8 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 3-12.

Voltage and current control of up to three contactors or proportional valves is provided by Gen4 size 8, and includes built-in freewheeling diodes for spike suppression. All I/O on the Gen4 size 8 controller is protected against short-circuit to the control logic positive and negative supply.

There is an exception to the protection for the Pusled Digital Output on the initial production of Gen4 size 8 Beta controllers. Initial production Beta controllers do not have protection for short-circuit of the Pulsed Digital Output to the control logic positive supply. Contact Sevcon for further details of the status of the protection.

Connectivity and interoperability with other system devices (for example another Gen4 size 8 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 DVT 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 Fault and Warnings in the Appendix).

Master-slave operation

The Gen4 size 8 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.

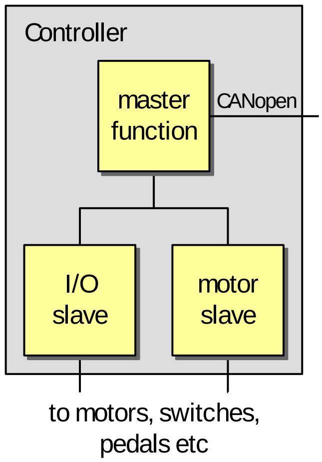

Figure 4 Single controller

Torque mode

In this mode Gen4 size 8 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 size 8 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 for the internal capacitors to discharge to less than 60V before handling the controller or working near exposed terminals.

Refer to Hazardous voltages may remain on the controller internally and on exposed power terminals after the main battery power connections and keyswitch power supplies have been removed if the controller is connected to a rotating permanent magnet motor.

Controller discharge profiles on page 5-16 for controller discharge times.

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.

If a PMAC motor is being used at the maximum motor speed the peak line to line back emf must not exceed the non-operational voltage limit specified in (add ref to section 4 input voltage table). The controller may be damaged if the back emf exceeds this level.

Do not tow vehicles that have PMAC motors, the motors act as generators and may cause high currents to flow in the motor, controller or battery system. If towed at a speed in excess of the vehicle rated speed the voltage generated by the motor may damage the controller or battery.

When a PMAC motor is acting as a generator, for example when braking or driving down hill, the short circuit current must not exceed the controller current rating. The short circuit current should be calculated for all vehicle speeds and must be less that the controller current rating. If the current is greater than the controller current rating then measures must be taken to protect the controller from the motor acting as a generator. Possible measures include adding a disconnect switch between the motor and controller on at least 2 out of the 3 phases, or adding fuses in each phase. Contact your local Sevcon representative for further information and guidance.

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 moulding.

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 size 8 motor controller should be carefully considered and relevant safety precautions taken. The Gen4 size 8 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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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 size 8 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 size 8 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 Limit[1].
- Hill Hold[1].
- Controlled Roll-Off[1].
- Speed mode (or speed control)[1].
- Electromechanical Brake output[1].
- Inching[2].
- Belly switch[2].
- Unused Driveability Profiles[3].

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.

In addition, the following features must be configured correctly

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

Fault detection and handling

There are five categories of faults as described in Table 1. For a detailed list of faults see Table 7**Error! Reference source not found.** on page 10.

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

3 Chapter 3: Installation

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Mounting Gen4 size 8

Location

The mounting location for the controller should be chosen with care taking into account the following considerations:-

- Do not mount the controller on the outside of a vehicle where it would be assessable to unauthorized personnel.
- Do not mount the controller where it may be susceptible to damage due to minor collisions or impact from road debris.
- Although the controller has a high degree of ingress protection avoid mounting the controller in locations where it may be submerged in water or subjected to long term exposure to jets of water. (Refer to section 4-7 for IP ratings).
- Take note of the thermal and EMC considerations as explained later in this section of the manual.

Electrical power terminals under the terminal cover on the controller present an electric shock hazard. High currents can also present a burn hazard. You must ensure that the electrical terminals of the controller are protected against access by unauthorized personnel.

Orientation

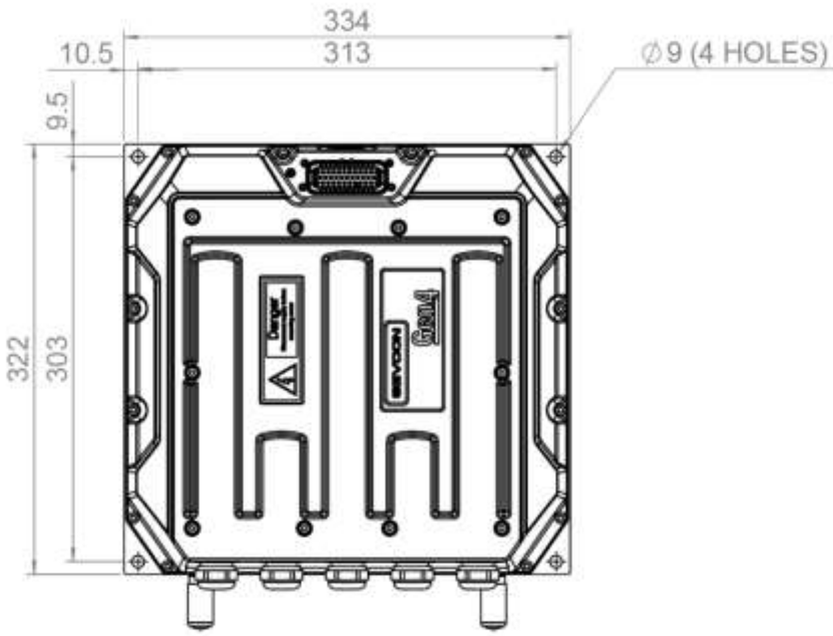
The controller can be mounted in any orientation.

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:

Liquid Cooled model:



The inverter should not be used as a stressed member.

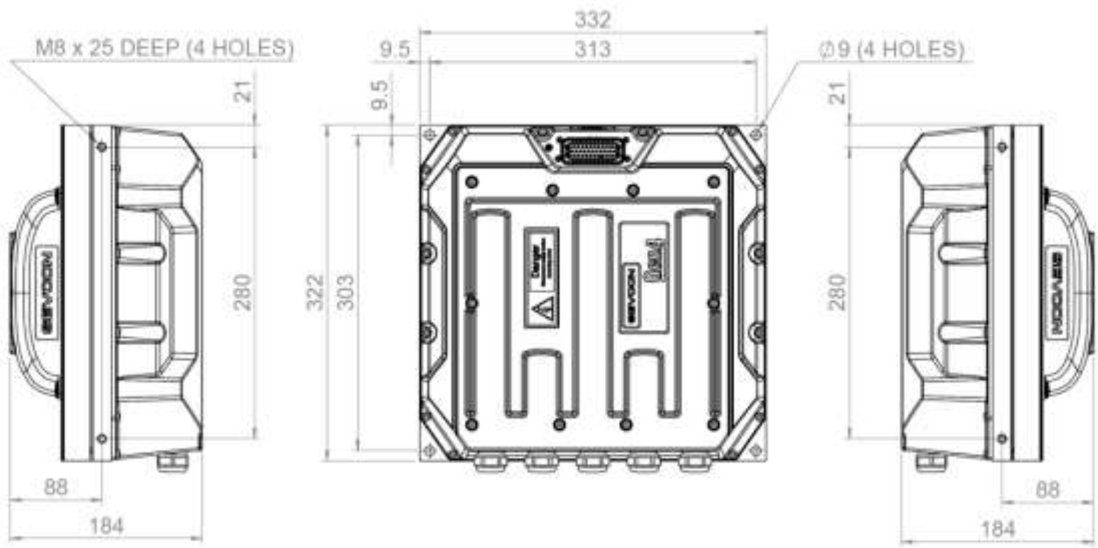
Flatness of mounting surfaces: <0.2mm

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

- Equipment required:
- ***4 x M8 socket cap head bolts (minimum strength 4.8), nuts and spring washers. Bolts need to be long enough to pass through 20mm of Gen4 size 8 base plate and your mounting surface thickness.***
- T hand-socket wrench or Allen key

Recommended torque setting: 11 Nm ± 2 Nm

Fan Cooled model:



The inverter should not be used as a stressed member.

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:

If the 4 x dia 9mm base holes are used:

- 4 x M8 socket cap head bolts (minimum strength 4.8), nuts and spring washers. Bolts need to be long enough to pass through 20mm of Gen4 size 8 base plate and your mounting surface thickness.
- T hand-socket wrench or Allen key

Recommended torque setting: 11 Nm ± 2 Nm

4 x M8 threaded side holes are provided on the side of the base plate as an alternative means of mounting the inverter. If this method is used:-

- 4 x M8 socket cap head bolts (minimum strength 4.8), nuts and spring washers. Bolts need to long enough to pass through any mounting framework or chassis and provide >16mm of thread engagement into the base plate.

Recommended torque setting: 11 Nm ± 2 Nm

Cooling requirements

To ensure you get the maximum performance from your Gen4 size 8 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 4-7). Various cooling options are available to assist with this.

The cooling method for a particular controller depends on controller part number. The options are:

- Liquid-cooled. This option provides the most effective cooling, if adequate heat exchange from coolant to ambient is provided. A water-glycol mixture with a flow-rate of 2 litre/minute should be sufficient to meet the ratings given in this manual.
- Fan-cooled finned heatsink. This option provides effective cooling of approx 0.05K/W provided adequate airflow is maintained.

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EMC guidelines

The following guidelines are intended to help vehicle manufacturers to meet the requirements 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 minimise, 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.

General measures

Power cables

Use screened power cable for all connections to the motor and the battery. Where cables pass through metal enclosures, such as at the motor and battery, use metal cable glands to connect the cable screen to the enclosure, ensuring that the various enclosures are linked with conductive braid to the vehicle chassis. The Gen4 size 8 itself is equipped with a metal gland plate for connecting the motor and battery cable shields to the heatsink of the Gen4 size 8 controller.

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.

The cable manufacturers' recommendations for minimum bend radius should always be followed.

Keep power cables at least 300mm from signal cables.

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 and speed feedback. Tie all wiring securely and ensure it always follows the same layout.

Measures required for specific signals

Battery power cables

Use screened cables. Use metal cable glands and connect the screen of the cable to the gland. Cables should be as short as possible. Minimise the loop area of the B+ and B- wiring. A common mode ferrite choke may be required.

Motor power cables

Use screened cables. Use metal cable glands and connect the screen of the cable to the gland. Cables should be as short as possible. Minimise the loop area of the M1 M2 M3 wiring. A common mode ferrite choke may be required

Motor encoder connection, types AB, UVW and Sin-Cos

The encoder cable must be as short as possible. A multi-core screened cable should be used. The inner cores should be used for the encoder supply and encoder ground and the AB or UVW or Sin-Cos signals. The cable screen should be connected to the control OV terminal. Ensure that the screen does not connect the motor chassis back to the control OV terminal to avoid motor power cable current returning through the encoder cable screen.

Motor encoder connection, resolver types

By “resolver” we mean a device consisting of a primary excitation winding (driven by a 10kHz sinusoidal carrier signal generated by the Gen4 size 8) and two secondary windings where the carrier signal is modulated at the rotational frequency by the sine and cosine of the rotor angle respectively.

The encoder cable must be as short as possible. Separate twisted-pair screened cables should be used for the primary excitation and the sine and cosine secondary signals. The inner cores should be used for the sinusoidal signals. The cable screen should be connected to the control 0V terminal. Ensure that the screens do not connect the motor chassis back to the control 0V terminal to avoid motor power cable current returning through the encoder cable screen.

CAN bus

A multi-core screened cable should be used. The inner cores must be twisted pairs. One twisted pair should be used for CANH and CANL. The other twisted pair should be used for CAN supply. Ensure that there is a common ground connection for all nodes on the CAN bus. If there is a node on the bus which is galvanically isolated from the Gen4 size 8 controller then the CAN ground on this node must be connected to the Gen4 size 8 controller control 0V. The cable screen should be connected to the control 0V terminal at the Gen4 size 8 controller

Keyswitch

The keywire should be as short as possible. Minimise the loop area of the loop formed by the keyswitch, keyswitch supply and the control OV return wire. Do not connect additional loads to the keyswitch wire.

Contactor drivers

Minimise the loop area formed by the contactor driver output and the contactor supply +. Use of twisted pair will reduce emissions. Use of screened cable with the screen connected to control OV will further reduce emissions. Generally, contactors driven with a configured PWM signal produce higher emissions than a contactor driven from a fixed DC voltage.

Throttle input

The throttle input is referenced to the controller control 0V connection, it is therefore very important that the throttle ground connection goes directly to the control 0V terminal on the controller. Ensure that there is no common ground path for the throttle with the keyswitch power connection, contactor drivers or any other power or switching loads on the vehicle. Screened cable for the throttle supply and wiper may be required for higher levels of immunity, the screen should be connected to control 0V.

Additional measures

Where it has not been possible to meet the required EMC specifications using the standard measures listed above it may be necessary to use one or more of the following measures:-

- Use of screened cable for all control connections
- Use of a Faraday cage around the controller and motor
- Addition of an LC filter on the keyswitch supply

- A common mode ferrite choke for all the small signal connections will attenuate common mode emissions

Problems to avoid

EMC is a complex subject and on a typical vehicle there are many potential radiators and recievers. Measures taken on a vehicle to improve EMC can unitentionally make the situation worse.

- Beware of devices that are connected to the small signal wiring which have a significant (>10nF) capacitance to vehicle chassis. The capacitance to vehicle chassis can cause currents to flow out of the Gen4 size 8 controller along the signal wiring to the device and back to the controller via the vehicle chassis.
- When using screened cable beware of generating ground loops in which currents may be induced or which may cause noise currents to flow via unintended paths.

Connecting power cables

See also the section on EMC.

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.

- Use screened power cables sized to suit the controller and application (see Table 2 below)
- M8 crimp ring lugs
- Crimp tool
- M8 wrench

Torque setting: 11 Nm ± 2 Nm

Installing cables at a different torque level to that recommended can result in poor electrical connection and risk of terminal overheating / fire.

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.

Screened cables and metal screened cable glands

A metal gland plate is fitted to the controller. Under no circumstances should the gland plate be removed.

When using metal cable glands ensure that the spring contact fingers within the gland connect to the cable screen.

Ensure that all high voltage power cables are electrically isolated from the cable glands on the Gen4 Size 8

Under no circumstances should any of the cable screens be connected to any power terminal or live conductor. Ensure that the cable screen is electrically isolated from the live inner conductor and the cable termination.

The metal cable gland locknut should be tightened to the metal cable gland through the cover and screeing plate to a torque of 12Nm ± 1.0 Nm

Chassis conection to heatsink.

The base plate of the Gen4 Size8 must be connected electrically to the chassis of the vehicle. The cross section of the connection must be equal or larger than the cross section of the incoming DC traction supply.

For some vehicle standards, it is required to fit a second earth connection between base plate and chassis. When using terminated shielded motor cables, this can be achieved by fitting an earth connection between motor case and vehicle chassis. If in doubt, contact Sevcon for further advice.

Fitting the Terminal Cover

- Ensure the lid seal is correctly positioned in its groove
- Position the cover ensuring it sits flat against the seal
- Fit the x10 M4 screws (provided).

Torque setting: 1.5Nm ± 0.1 Nm

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.

The following table (Table 2)gives guidance on the cable size needed for various currents in screened power cable, not grouped with other cables, in 30°C ambient with 60°C temperature rise on the cable surface.

Table 2: Guidance on rating of screened cable

Gen4 size 8 average (rms) current	Cable sizes	
	metric	US (approx equivalent)
175 A	25 mm^2	4 AWG
215 A	35 mm^2	2 AWG

275 A	50 mm^2	1 AWG

Fuse rating and selection

The traction supply must be fused to protect the vehicle wiring and the Gen4 size 8 in the event of a fault. Recommended ratings :-

Fuse current rating	425A
Fuse voltage rating	600V dc

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 size 8. Never force a connector. Connectors are keyed to prevent incorrect insertion.

See also the section on EMC.

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 the section on EMC.

If your system has more than one CAN node, connect the nodes in a 'daisy chain' arrangement (Figure 5) and terminate the connections of the two end nodes with a 120 Ω resistor. If the end node is a Gen4 size 8, 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.

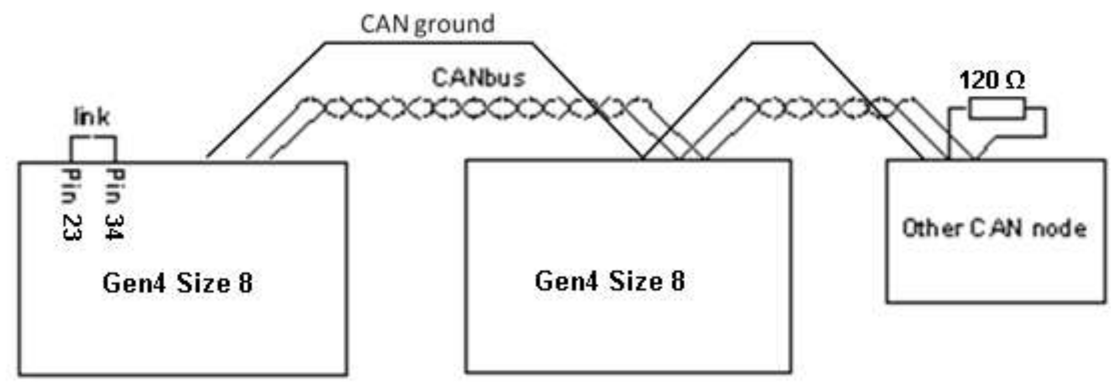


Figure 5 CAN node termination

Signal connections

Do not use contactors which have built in 'economiser' circuits, the internal circuits are not compatible with the controller and may cause malfunction or damage. The same power reduction can be achieved with a standard coil by using the configurable pull-in and hold voltage settings.

Signal connections are made to Gen4 size 8 via a 35 way AMPSeal connector.

There are a small number of differences between "Alpha" prototypes and "Beta" production units. The most important difference is the introduction of "Pulsed Digital Output" and "Pulse Enable Input" functions.

Gen4 size 8 Beta controllers will not operate the motor unless a suitable input signal (square-wave, amplitude 10V, frequency 1kHz, duty cycle 50%) is supplied to the "Pulse Enable Input" pin. A suitable signal can be supplied by linking Pulsed Digital Output to Pulse Enable Input on the 35-way customer connector.

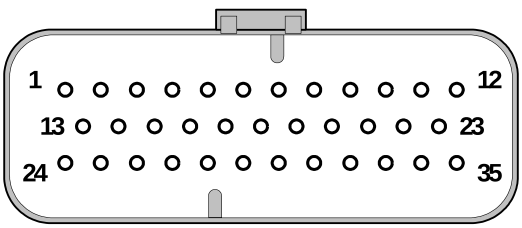


Figure 6 Customer Connector

Pins are protected against short-circuits to the control logic supply positive or negative terminals.

There is an exception to the protection for the Pusled Digital Output on the initial production of Gen4 size 8 Beta controllers. Initial production Beta controllers do not have protection for short-circuit of the Pulsed Digital Output to the control logic positive supply. Contact Sevcon for further details of the status of the protection.

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 (Vc)	Power	From 'dead' side of key switch via suitable fuse	V = 24V (nominal) I = 7A (Total of all contactor output currents plus 1.0A)	This input supplies power from the low voltage source for all the logic circuits. The unit cannot operate without "Key switch in" supply. Referred to as Vc in this table.

Pin	Name	Type	What to connect	Maximum rating	Comment
2	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 = Vc	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 Vc) to de-activate the load.
3	Contactor out 2	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 = Vc	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 Vc) to de-activate the load.
4	Contactor out 3	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 = Vc	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 Vc) to de-activate the load.
5	Pot. 1 wiper in (AIN1_B)	Analog	From potentiometer 1(B) wiper.	V = 9.5 V Zin = 22 kΩ	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
6	Pot. 2 wiper in (AIN2_B)	Analog	From potentiometer 2(B) wiper.	V = 9.5 V Zin = 22 kΩ	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
7	Resolver Excitation-	Analog	To the primary of the motor's resolver (if fitted)	V = 7.2Vpk-pk I = 100mA	

Pin	Name	Type	What to connect	Maximum rating	Comment
8	Resolver Excitation +	Analog	To the primary of the motor's resolver (if fitted)	V = 7.2Vpk-pk (2.5V rms) I = 100mA	
9	Encoder power supply +	Power	To the positive supply input of the speed encoder	I = 100 mA V = 0V to +10V, set in software	Check the speed encoder you use is compatible with Gen4 size 8. See page 6-13 for configuration details.
10	CAN ground	Power	To the ground of the external CAN bus		
11	CAN High	Comms	CANbus High signal	V = 5 V	Maximum bus speed 1 Mbits/sec Alternative connection to pin 12
12	CAN High	Comms	CANbus High signal	V = 5 V	Maximum bus speed 1 Mbits/sec Alternative connection to pin 11
13	Control 0V	Power	Logic power supply ground connection	0V	
14	Function in "Alpha": Digital Input 2	Digital	From digital switch input 2. In a basic configuration this is usually the reverse switch.	Type A V = Vc See Table 4	See note to Table 4
	Function in "Beta": Pulsed Digital Output	Out	Connect to Vehicle Control Unit (VCU) input with pull-up to provide a 1kHz 50%-duty pulse output indicating controller healthy.	V = Vc Current 1A	This pin is used as Pulsed Digital Output from Beta version onwards
15	Function in "Alpha": Digital Input 4	Digital	From digital switch input 4.	Type B V = Vc See Table 4	See note to Table 4
	Function in "Beta": Digital Input 2	Digital	From digital switch input 2. In a basic configuration this is usually the reverse switch.	Type A V = Vc See Table 4	See note to Table 4
16	Function in "Alpha": Digital Input 6	Digital	From digital switch input 6.	Type B V = Vc See Table 4	See note to Table 4

Pin	Name	Type	What to connect	Maximum rating	Comment
	Function in "Beta": Digital Input 4	Digital	From digital switch input 4.	Type B V = Vc See Table 4	See note to Table 4
17	Pot. 1 wiper in (AIN1_A)	Analog	From potentiometer 1(A) wiper.	V = 9.5 V Zin = 22 kΩ	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
18	Pot. 2 wiper in (AIN2_A)	Analog	From potentiometer 2(A) wiper.	V = 9.5 V Zin = 22 kΩ	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
19	Encoder A input	Digital pulse / Analog	A channel of AB type encoder, SIN from SIN/COS or resolver type encoder	10V for AB type encoder 5V for SIN/COS, Resolver Sin Hi	Controller must be set up correctly for the motor speed feedback type. Only one of AB, SIN/COS and resolver can be used at the same time.
20	Encoder B input	Digital pulse / Analog	B channel of AB type encoder, COS from SIN/COS or resolver type encoder	10V for AB type encoder 5V for SIN/COS Resolver Cos Hi	Controller must be set up correctly for the motor speed feedback type. Only one of AB, SIN/COS and resolver can be used at the same time.
21	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.
22	CAN Low	Comms	CANbus Low signal	V = 5 V	Maximum bus speed 1 Mbits/s. Alternative connection to pin 23

Pin	Name	Type	What to connect	Maximum rating	Comment
23	CAN Low	Comms	CANbus Low signal	V = 5 V	Maximum bus speed 1 Mbits/s. Alternative connection to pin 22
24	Protected key-switch	Power	To supply the high side of contactor or valve coils.	V = Vc	Use to supply coils controlled by pins 2 – 4.
25	Digital Input 1	Digital	From digital switch input 1. In a basic configuration this is usually the forward switch.	Type A V = Vc See Table 4	See note to Table 4
26	Function in "Alpha": Digital Input 3	Digital	From digital switch input 3. In a basic configuration this is usually a 'drive enable' switch, e.g. foot switch.	Type A V = Vc See Table 4	See note to Table 4
	Function in "Beta": Digital Input 3	Digital	From digital switch input 3. In a basic configuration this is usually a 'drive enable' switch, e.g. foot switch.	Type B V = Vc See Table 4	See note to Table 4
27	Function in "Alpha": Digital Input 5	Digital	From digital switch input 5.	Type B V = Vc See Table 4	See note to Table 4
	Function in "Beta": Pulse Enable Input	Digital	Connect 1kHz 50% duty pulse train to allow power frame functionality to be enabled. If this input is absent or outside specified range then the Gen4 Size 8 power frame will be disabled.	Internal pull-up resistor 6k8 to 15V. Minimum amplitude 8V. Maximum amplitude Vc.	This pin is used as Pulse Enable Input from Beta version onwards. For stand-alone operation it may be connected to pin 14 (Pulsed Digital Output) so that the controllers own "healthy" output will allow the power frame to be enabled.
28	Analogue input 3 (AIN3)	Analogue	To motor temperature thermistor (PTC type)	V = 13V I = 3mA Z_{out} = 4.7kΩ	
29	AIN1 Vcc	Power	To supply potentiometer or analogue input device 1	I = 100 mA V = 0V to +10V, set in software	Check the analogue input device or pot you use is compatible with the voltage selected. See page 6-13 for configuration details.

Pin	Name	Type	What to connect	Maximum rating	Comment
30	AIN2 Vcc	Power	To supply potentiometer or analogue input device 2	I = 100 mA V = 0V to +10V, set in software	Check the analogue input device or pot you use is compatible with the voltage selected. See page 6-13 for configuration details.
31	Encoder "U" input	Digital pulse / Analog	U channel of UVW type encoder; or the –ve terminal of the SIN coil of resolver.	V = 10V for UVW Resolver Sin Low	Controller must be set up correctly for the motor speed feedback type. UVW and resolver are not compatible at the same time.
32	Encoder "V" input	Digital pulse / Analog	V channel of UVW type encoder; or the –ve terminal of the COS coil of resolver.	V = 10V for UVW Resolver Cos Low	Controller must be set up correctly for the motor speed feedback type. UVW and resolver are not compatible at the same time.
33	Encoder "W" input	Digital pulse / Analog	V channel of UVW type encoder	V = 10V typical	Controller must be set up correctly for the motor speed feedback type.
34	CAN termination	Comms	To terminate a Gen4 size 8 CAN node link pin 22 to pin 34. This connects a 120Ω termination resistor, mounted inside the controller, across the CANbus.		Make the connection only if the Gen4 size 8 is physically at the end of the CANbus network (see 'CANbus termination' on page 3-11.
35	CAN supply	Power	To supply external devices referenced to CAN ground	V = 24V I = 100mA	Referenced to CAN ground. Isolated from Control 0V.

Table 3 Connector A pin out and wiring information

Digital Input Type	Impedance to Vc	Impedance to Control 0V
A	9k	9k
B	13k	9k

Table 4: Impedance at Digital Input Pins

Note to Table 4:

Configure the digital input switches as active-high (switched to +24V) or active-low (switched to 0V). 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 Vc. The input sinks current in active-high configurations and sources current in active-low configurations.

4 Chapter 4: Specification

Electrical

Input voltage – control supply

Nominal working voltage:	12V to 24V (12V only on air cooled version)
Working voltage limits:	8V to 36V (max 15V on air cooled version)
Supply voltage droop:	Vnom to 0.5 x Vnom for 10 ms Vnom to 0 V for 1 ms
Input protection:	Input protected against reverse connection of battery by input diode

Input voltage – traction supply

Nominal working voltage:	128V to 350V
Working voltage limits:	80V to 400V dc
Non-operational overvoltage limits:	0V to 450V dc
Input protection:	Input protected against reverse connection of battery by control of the line contactor

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 7 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 size 8 detects valid output loads are present before applying drive current.

Repetitive short circuits may damage the controller.

Output ratings

The rating achievable in a particular application must be checked.

Gen4 Size 8 Air-cooled

Ratings at 25°C ambient and air inlet at 25°C.

Maximum output current (boost)	400A rms
Maximum output current (rated 2 minutes)	300A rms
Continuous output current (1hr rated)	165A rms

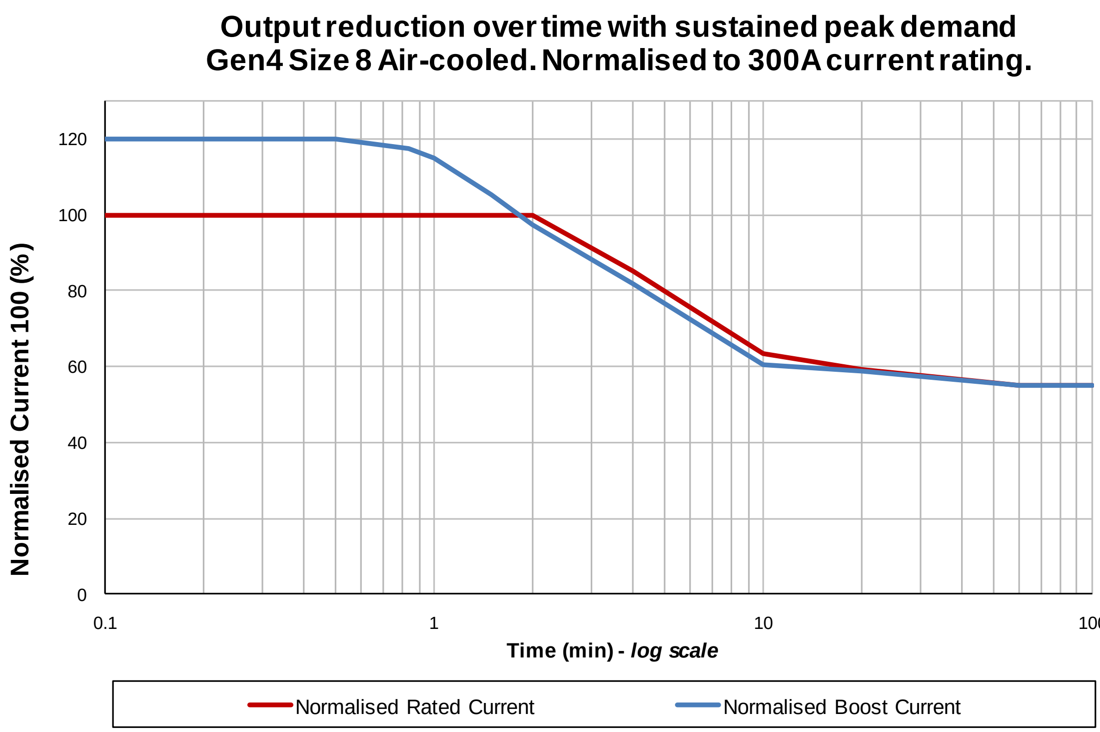


Figure 7 Output current for various durations of current demand, air cooled

Gen4 Size 8 Liquid-cooled

Ratings at 25°C ambient and water-glycol at 2.5 litre/min with inlet temperature 30°C.

Maximum output current (boost)	400A rms
Maximum output current (rated 2 minutes)	300A rms
Continuous output current (1hr rated)	190A rms

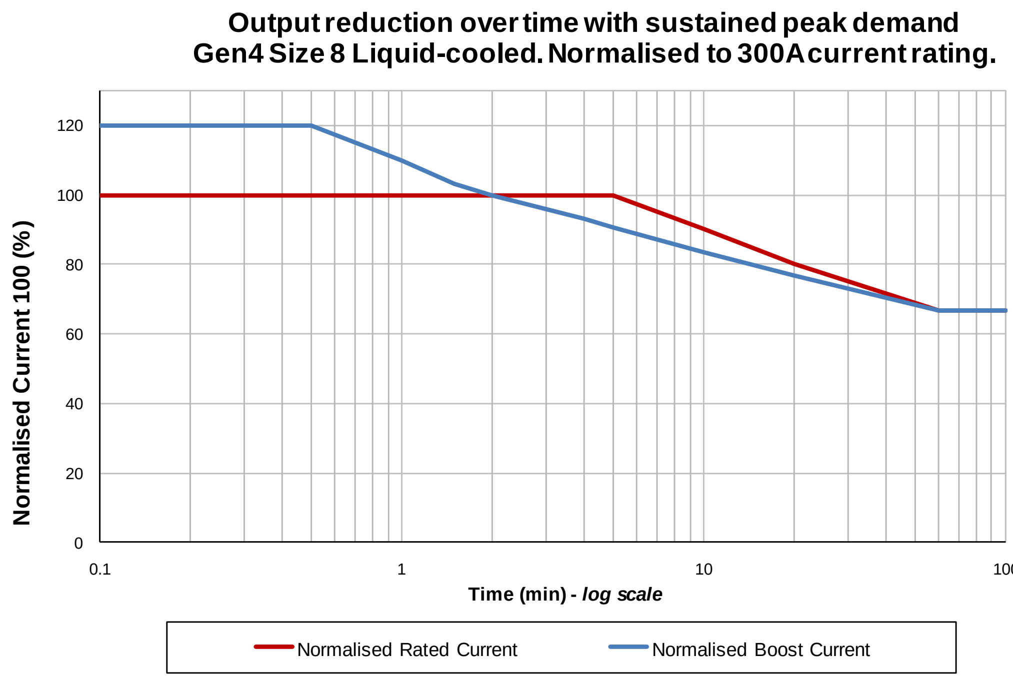


Figure 8 Output current for various durations of current demand, liquid cooled

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:	4 digital switch inputs (software configurable polarity). Active low inputs < 2.6V, active high inputs > Vb – 2.6 V Note: Digital inputs 5 and 6 are reserved for future use.
Analog inputs:	4 general purpose inputs which can be used for 2-wire potentiometers or dual throttle type devices. Motor thermistor input All analog inputs can also be used as digital 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 or resolver inputs provided for control of permanent magnet motors
Resolver excitation	Two outputs, Exc+ and Exc-, provide excitation to a speed feedback resolver. Each output is 7.2V max pk-pk (2.5V rms), 100mA, protected against short-circuit. Consult the ‘Resolver’ section in the System Design section of this document for important information about resolver feedback.
Pulsed Digital Output	Open-drain output. Provides 1kHz 50%-duty pulsed current sink when the controller is healthy and no safety problem has been detected. In stand-alone applications the controller may monitor its own output using the Pulse Enable input. In VCU applications the VCU can use the output to determine the safe operation of the controller.
Pulse Enable Input	Input for 1kHz 50%-duty pulsed voltage source or open-collector transistor. Input amplitude can be between 8V and Vc. A pull-up to 15V is provided so that open-collector outputs may be used. The controller power frame will not operate if this input is missing or outside specification.

Isolation

Power terminals to the case:	Withstands 2500 V ac
Power terminals to control terminals and CAN bus	Withstands 3750 V ac
Control terminals and CAN bus to the case	Withstands 3750 V ac
Control terminals to CAN bus	Withstands 3000 V ac

EMC

1 Radiated emissions:	2 EN12895 (Industrial Trucks – Electromagnetic Compatibility) 3 EN 55022:1998, 6, class B 4 EN 12895:2000, 4.1 Emissions. When part of a system with a motor operating, 5 FCC Part 15, Radiated Emissions. Meets the standards given in FCC Part 15, Section 15.109: ISO 11452:2007 as an Electronic Sub-Assembly (ESA). ISO 11451:2007 (for vehicles) UNECE Reg 10 (limits for ESAs and vehicles)
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 ISO 11452:2007 as an Electronic Sub-Assembly (ESA). ISO 11451:2007 (for vehicles)
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 ISO 10605:2008 15 kV contact discharge without permanent damage 25 kV air discharge without permanent damage 8 kV contact discharge (recoverable loss of function) 15 kV air discharge (recoverable loss of function)
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 ISO 6469 Road vehicles. Requirements for safety UNECE Reg 100 Electric vehicles - Construction & safety
Designed to meet in future:	BS ISO 26262:2011 Road vehicles - Functional safety, when configured as a Motor Slave

Initial production of Gen4 size 8 Beta controllers does not meet ISO 26262 but it is intended to do so in future. Check with your local Sevcon representative for the status of ISO 26262 implementation.

X and Y Capacitance

X capacitance (DC+ to DC-)	1880uF
Y Capacitance (DC Link to Heatsink	28nF

Mechanical

Operating environment

Operating temperature:	**6** Liquid cooled: **7** -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) When operated with liquid-cooled heatsink, the maximum coolant inlet temperature shall be 40°C and the maximum coolant temperature rise shall be 25°C. Fan cooled: The operating range for the fans is -10°C to +70°
Non-operation temperature:	**8** Liquid cooled: -40°C to +85°C (can be stored for up to 12 months in this ambient range)

	Fan cooled: The storage temperature for the fans is -30°C to +70°C
Humidity:	95% at 40°C and 3% at 40°C
Ingress of dust and water:	Liquid cooled: IP66 Fan cooled: The fans are rated IP55
9 Thermal shock:	0 EN60068-2-14, Test Na

Shock and vibration

1 Repetitive shock:	2 50 g peak 3 orthogonal axes, 3+ and 3– in each axis, 11 ms pulse width
3 Drop test:	4 BS EN 60068-2-32:1993 Test Ed: Free fall, appendix B, Table 1
5 Bump:	6 40 g peak, 6 ms, 1000 bumps in each direction repetition rate 1 to 3 Hz.
7 Vibration:	8 3 g, 5 Hz to 500 Hz
9 Random vibration:	20 20 Hz to 500 Hz, acceleration spectral density 0.05 g2/Hz (equivalent to 4.9 grms)

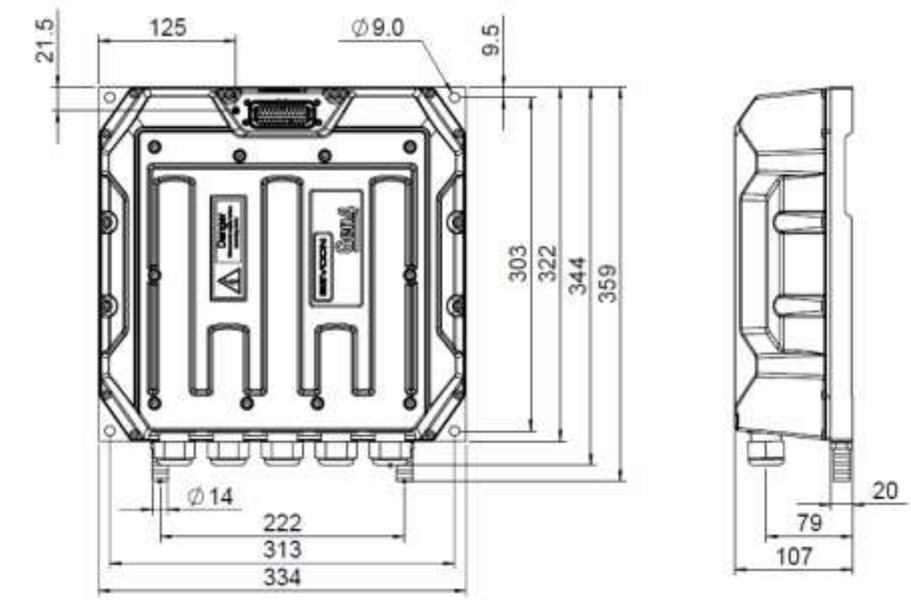
Weight

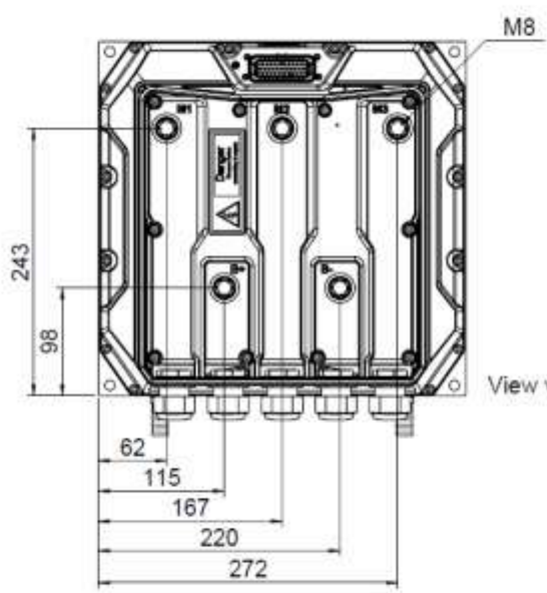
Controller weight

Liquid cooled	10kg
Fan cooled	15kg

Dimensions Gen4 size 8

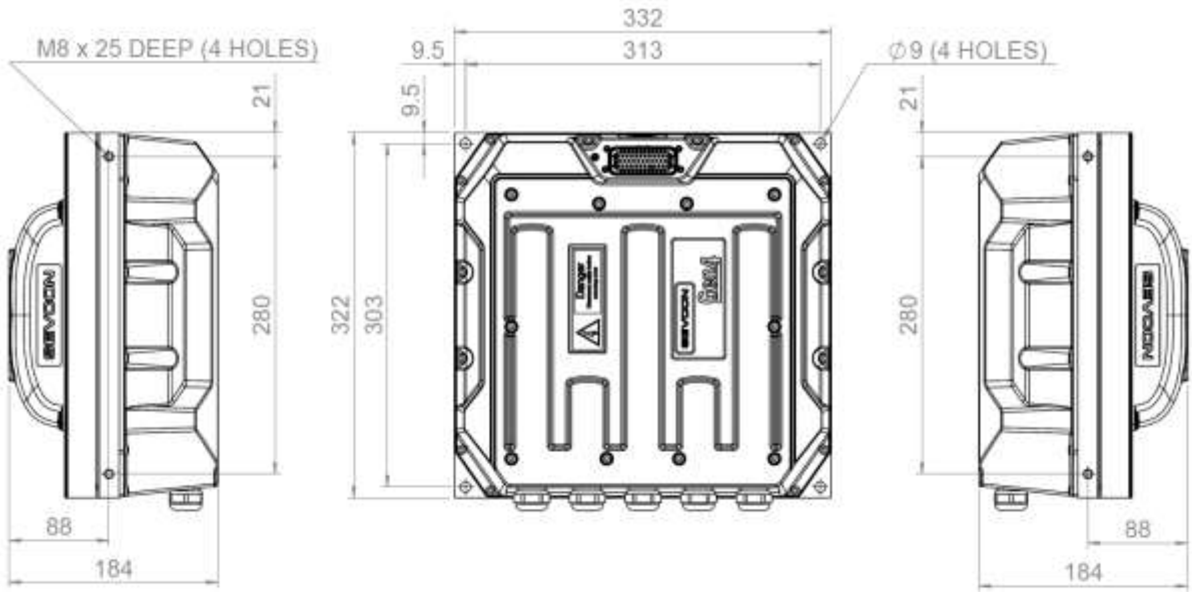
Liquid Cooled Model:





View with Terminal Cover removed

Fan Cooled Model:



5 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 5-8).

Active Short Circuit Protection

The Gen4 Size 8 controller is capable of driving both Induction and Permanent Magnet AC motors beyond their base speed, into a region of higher speed 'field weakened' operation.

PMAC motors produce an inherent back EMF, which can reach very high levels during high speed operation. Field weakening is used to keep the back EMF below the level of the DC link power supply.

In event of a serious system or controller fault during operation above the configured upper speed threshold, the active short circuit function will clamp the back EMF produced by a rotating high speed motor. This dissipates the system energy in the motor at the motor short circuit current.

⚠ if the peak level of back EMF from a PMAC motor exceeds 450V then the Gen4 Size 8 can damaged.

⚠ active short circuit can not operate if the 12V/24V power supply to the Gen4 Size 8 is removed the active short circuit produced by the motor must be less than the maximum current rating of the Gen4 Size 8 unit.

The high voltage DC Battery supply to the Gen4 Size 8 will help act as a clamp on maximum back EMF produced by the motor. Ensure that any contactor/interlocks are not opened during high speed operation to help ensure that excessive levels of back are not experienced.

Active Short Circuit is configured OFF by default and is configured for use with the following objects:

Feature	Object index	Notes
Active Short configured	4658h	Enable/Disable Active Short Functionality
Active Short Lower Speed Threshold	4659h	Sets Lower Speed Threshold to exit Active Short Circuit
Active Short Upper Speed Threshold	4660h	Sets Upper Speed Threshold to start Active Short Circuit

Contact Sevcon for assistance on setting up the active short circuit function if the target motor is capable of producing a back emf >450V peak at the required maximum speed of operation.

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 size 8 is equal to the breakdown torque. Select a motor with a breakdown torque rating greater than the peak torque required.

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;

$$T = \frac{T_{\max}}{\left(\frac{\omega}{\omega_{rated}}\right)}$$

In the high speed region;

$$T = \frac{T_{\max}}{\left(\frac{\omega}{\omega_{rated}}\right)^2}$$

This is shown in Figure 9. Select a motor with a torque rating greater than the peak torque required.

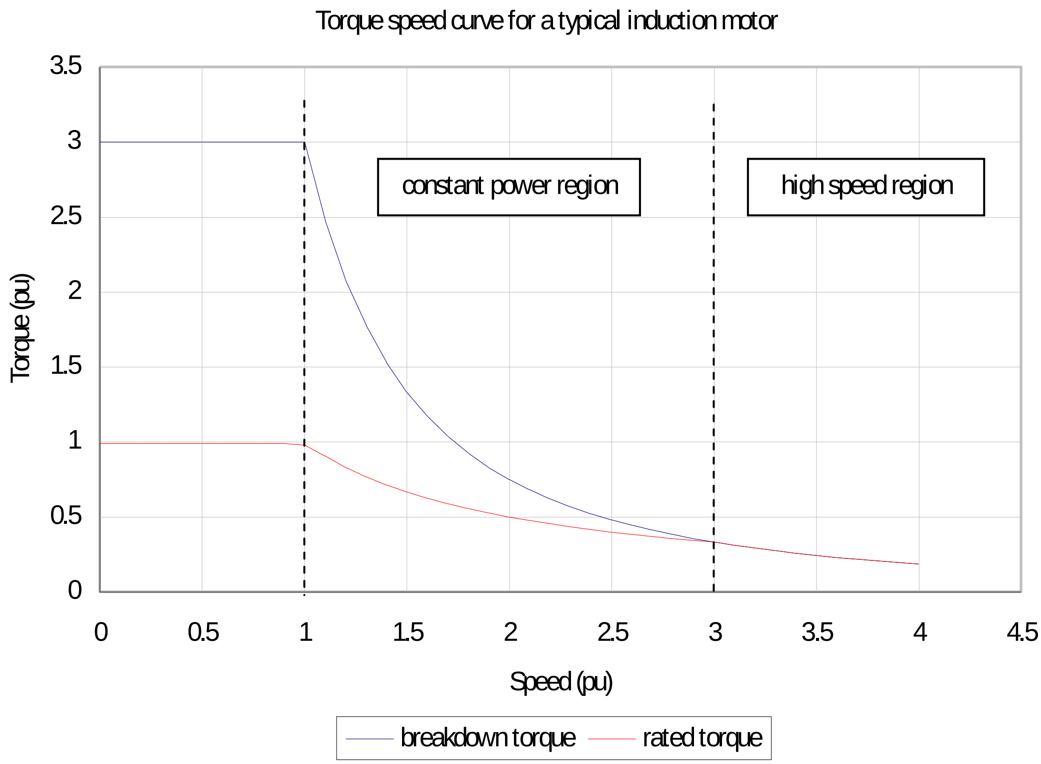


Figure 9 Torque speed curve

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.

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 size 8 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 size 8 controller are described below.

Current and power ratings considerations

Consider the following when choosing the appropriate Gen4 size 8 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 10).

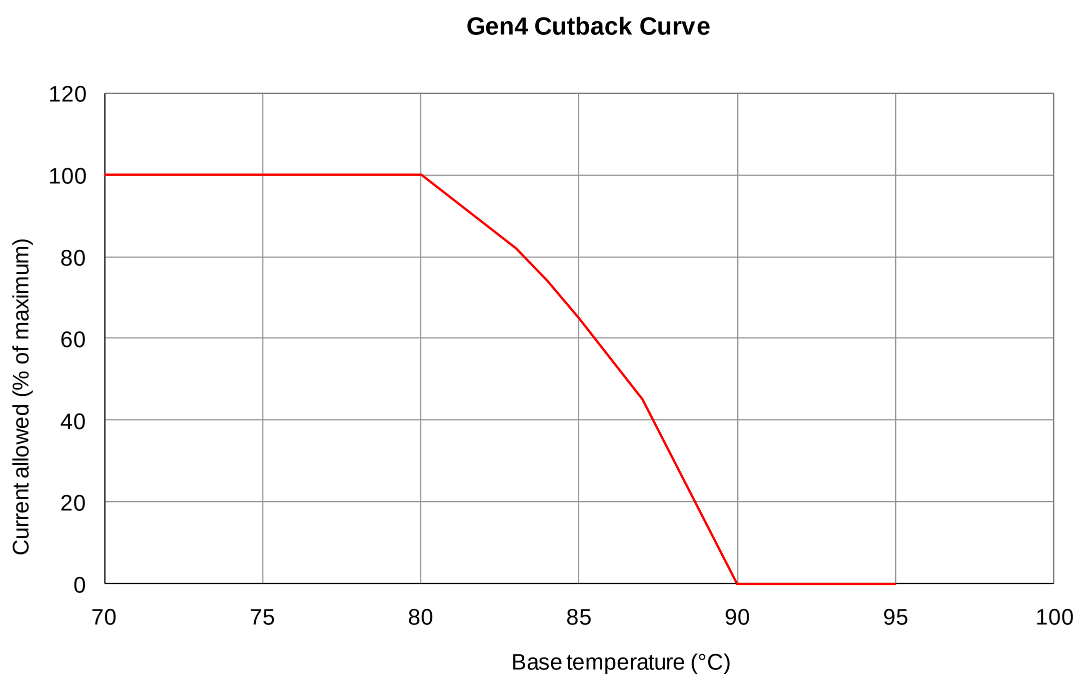


Figure 10 Current allowed vs. controller base temperature

The Gen4 Size 8 also looks at a number of internal temperature measurements and estimates. These can also influence the thermal cutback operation, depending on installation and operating duty cycle

---

Circuit configuration

Once motor size is determined the application circuit configuration can be defined. A basic single traction configuration (Figure 11) 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 3-12 to see what each I/O signal is capable of doing as you design your system.

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Single traction wiring diagram

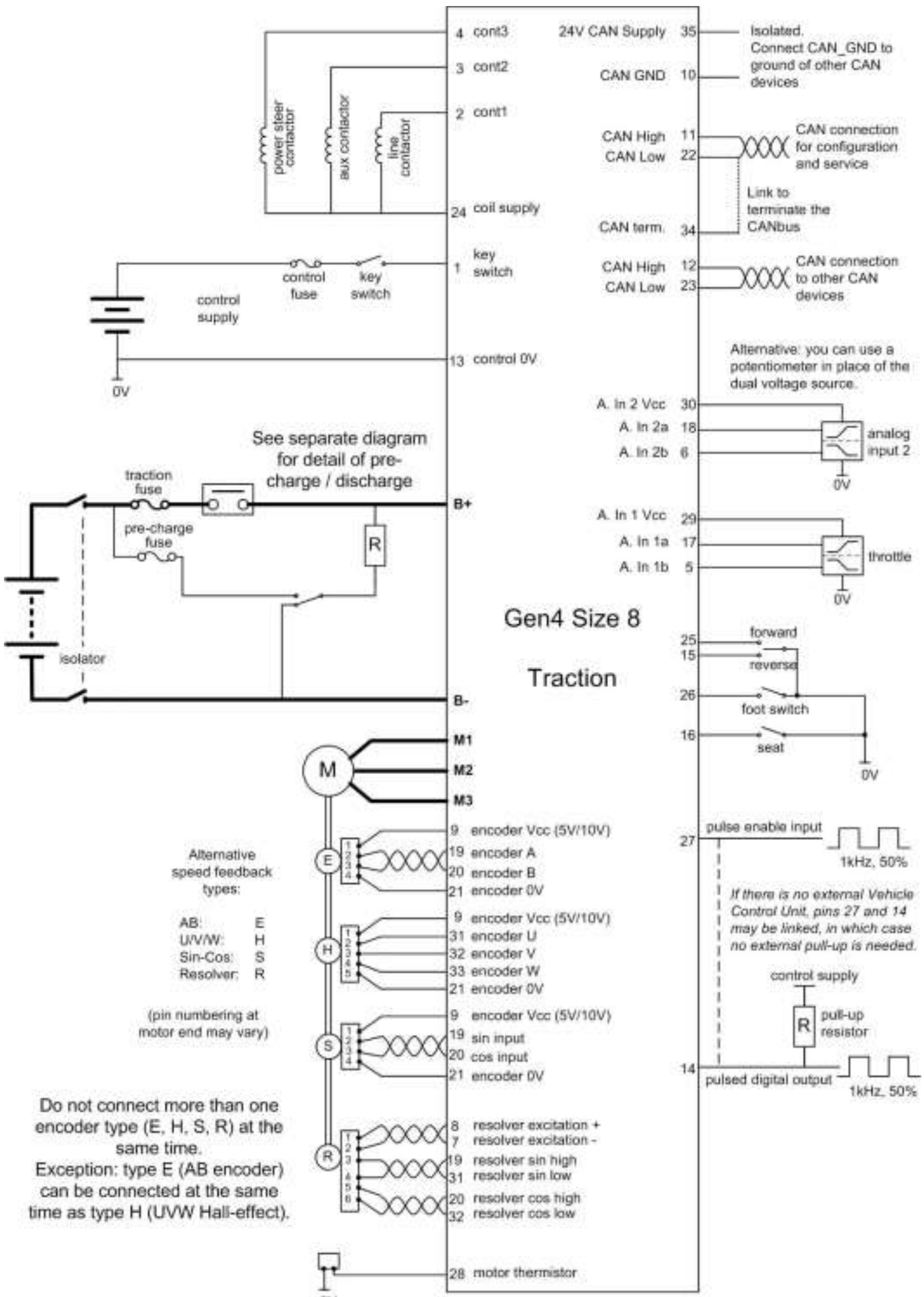

Figure 11 Single traction wiring diagram - Gen4 Size 8 Beta

Figure 11 shows line contactor coil connected to and driven directly from the Gen4 Size 8. This is only possible if the unit is configured to receive actual battery voltage via the CANBus as part of a power on start-up sequence.

Twin motor systems

A twin motor system may be powered by two Gen4 size 8 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.

Auxiliary components

Main Contactor and Precharge circuit

Gen4 size 8 does not support line contactor or precharge functionality. An external device must be used to isolate the Gen4 size 8 from the vehicle battery. This external device is also responsible for any capacitor precharging required to prevent damage to the line contactor tips.

It is recommended that the precharge circuit is connected as shown in Figure 12 Line contactor and pre-charge wiring diagram

The circuit is intended to operate in the following manner:-

- When K1 and K2 are not energised resistor R1 ensures that the controller dc bus capacitance is quickly discharged to a safe voltage.
- At startup K1 must be energised, the controller DC bus voltage should be monitored and should have reached 90% of the battery voltage within 5s.
- If the dc bus voltage is more than 90% of battery voltage the main contactor K2 can now be closed. If the dc bus voltage is too low this indicates a fault and K1 should be de-energised.
- At shut-down K1 and K2 may be de-energised simultaneously. K1 will connect R1 from B+ to B- thus discharging the controller dc bus.

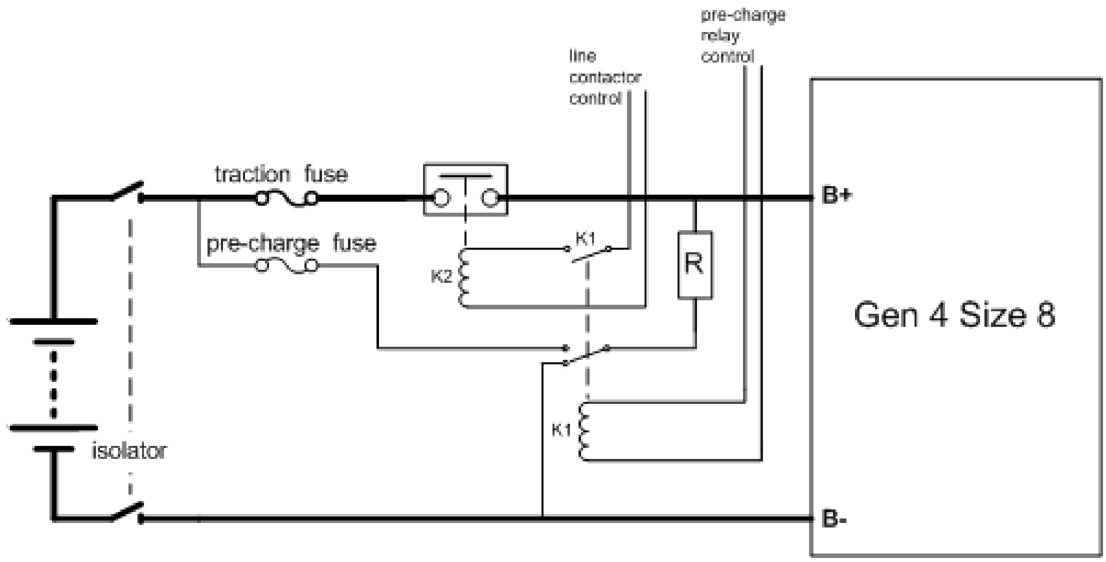

Figure 12 Line contactor and pre-charge wiring diagram

Components required for the precharge and discharge circuit are listed in the following table

Name	Function	Required specification	Comment
F1	Pre-charge fuse	20A 600V dc Slow blow	
F2	Main traction fuse	425A 600V dc Semiconductor fuse	
K1	Pre-charge and dis-charge contactor	Single pole change over with auxiliary contact 600V dc 10A	Must be wired such that in the normally closed position R1 is connected to the B- terminal.
K2	Main line contactor	Single pole 600V dc 500A	Must be interlocked so that K2 can only close if K1 is energised.
R1	Pre-charge and dis-charge resistor	Resistance 100Ω to 1kΩ Pulse voltage 600V Energy pulse 200J Power 50W	Must be overload protected with thermal cut out and or fuse

Failure to use a capacitor precharge circuit may lead to damage to the controller. Failure to use a discharge circuit may result in the dc bus capacitors remaining charged at hazardous voltages for several minutes.

Contactors controlled from Gen4 size 8

The controller can drive any contactor with coil voltages from 12 V to the control supply. It is worth considering the use of contactors with a rated coil voltage suitable for the lowest expected operating voltage of the control supply. The contactor drive outputs can be set to voltage-control mode, in which PWM output is used to maintain the requested coil voltage. 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 Protected Keyswitch pin provided (see Table 3).

35 Way AMPSeal Connector Kit

Kit consists of Gen4 size 8 mating 35 way AMPSeal connector and pins, Sevcon p/n 661/27901

Emergency stop switch

Refer to the appropriate truck standards.

Key switch fuse F2

Use a fuse rated for the sum of the drive currents plus 1A for internal circuits. In the following example there are two contactors each drawing 2 A:

Device	Current
Power steer contactor	2 A
Pump contactor	2 A
Gen4 size 8 control circuits	1 A

Fuse choice: 5A.

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.

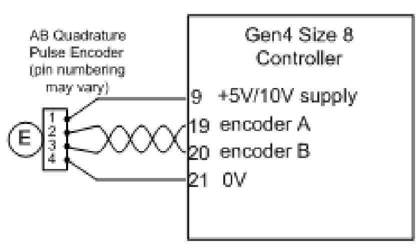

Figure 13 - Sample wiring for an AB quadrature speed encoder

You can use the following types of quadrature 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 ($\mathbf{f}_{max}$). 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
64	10000

For other types of encoder and motor use the formulae:

$$f_{\max}(Hz) = \frac{n(per\,revolution) \times N(rpm)}{60}$$

with $\mathbf{f}_{max}$ limited to 13.3 kHz, and

$$N_{\max}(rpm) = \frac{20000(rpm)}{(p/2)}$$

Encoder PPR is set at 6090_h. Additional encoder configuration (pull-up, supply, etc) is set at 4630_h.

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.

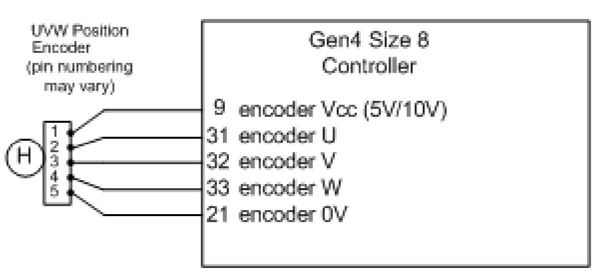

Figure 14 - Sample wiring for a UVW commutation sensor

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:

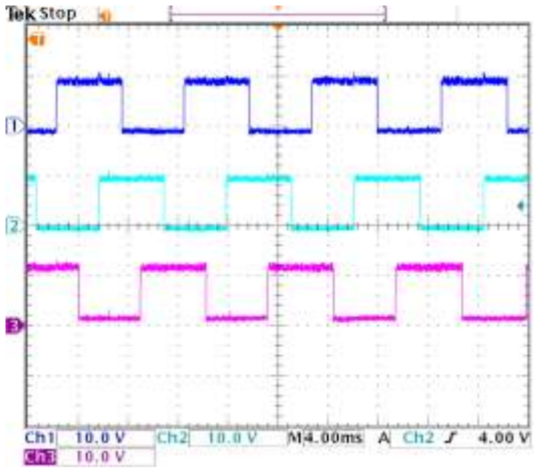

Figure 15 - Example pulse train from a UVW commutation sensor

Sin-Cos Commutation Sensor

Analogue sin-cos encoders generate a number of sin and cosine waves per mechanical rotation of the motor.

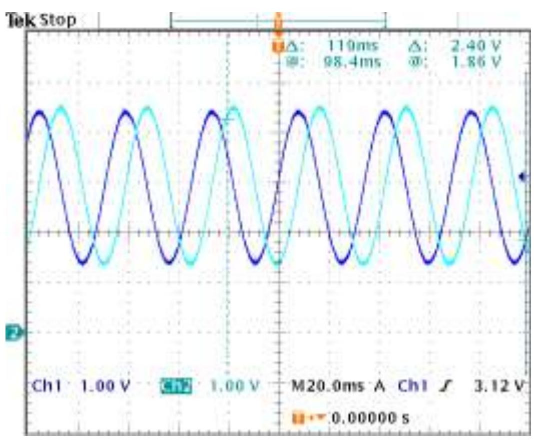

Figure 16 - Example of signals from a sin-cos position sensor

The controller is able to control motors with sin-cos sensors that produce multiple sin and cosine waves per mechanical rotation. However, it is required that the number of pole pairs in the motor is an integer multiple of the number of sin-cos waves per rotation. That is to say, the number of waves per electrical rotation of the motor should be an integer number.

Examples:

- an encoder that produces 3 waves per rotation can be used with motors that have 3 pole pairs, 6 pole pairs, 9 pole pairs, etc…
- an encoder that produces 5 waves per rotation can be used with motors that have 5 pole pairs, 10 pole pairs, 15 pole pairs, etc...
- an encoder that produces 1 wave per rotation can be used with motors that have 1 pole pair, 2 pole pairs, 3 pole pairs, etc…

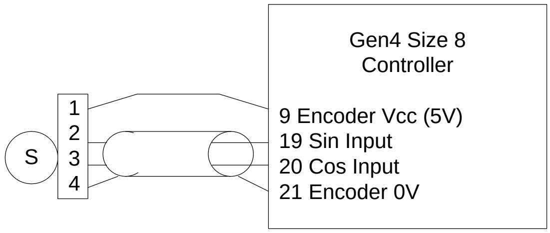

Figure 17 - Sample wiring for a sin-cos commutation sensor

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 9. This should be done by setting the encoder configuration object dictionary entry at 4630_h.

When a Sin-cos encoder is used there should be no connection of other encoder types. Pins 31, 32, and 33 must be left unconnected.

Resolver

The resolver is a speed feedback device which requires a sinusoidal excitation (provided by the Gen4 size 8 controller). The speed feedback consists of two pairs of signals: a Resolver Sin pair and a Resolver Cos pair. These signals consist of the excitation frequency modulated by the sin or cosine (respectively) of the rotor position.

The following issues are important when selecting a resolver: mechanical, environmental and electrical specification.

Mechanical specification includes e.g. material; dimensions; max speed; max angular acceleration; rotor moment of inertia; resistance to shock; resistance to vibration; permitted axial offset; permitted radial runout (deviation from true circle) of motor shaft.

Environmental specification includes: max operating temperature (including self-heating); IP rating.

Electrical specification includes: number of pole pairs (p); transformer ratio (Rt); angular error tolerance; residual voltage; recommended input voltage; recommended operating frequency; maximum primary current.

Regarding mechanical and environmental specification, the user must select a resolver appropriate to the environment of the application.

Regarding electrical specification, the following features are required of a resolver to work with the Gen4 size 8:

- Number of pole pairs = 1 or for multi pole pair resolvers a whole number divisor of the number of motor pole pairs.
- Transformer ratio = 0.5 or 0.29 (according to the Gen4 size 8 model)
- Excitation frequency = 10kHz
- Excitation voltage = 2.5Vrms nominal (a resolver specified to 2.5Vrms or higher will be acceptable)

Gen4 size 8 Beta controllers are built specifically to operate with a resolver transformer ratio of either 0.5 or 0.29. For a particular Gen4 size 8 model, the resolver transformer ratio cannot be configured to a value different from the value stated for that model.

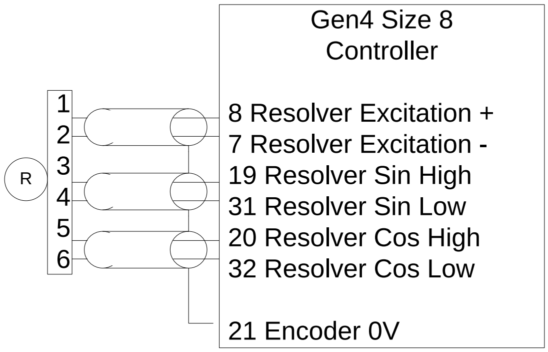

Figure 18 - Sample wiring for a resolver

Note the screen for the encoders should be open circuit at the motor end but connected to Encoder 0V at the inverter end..

Only connect a single type of encoder to the Gen4 Size 8 at any given time. One exception is a supported option to connect both AB and UVW for a PMAC motor.

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 or coolant for the liquid 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 DVT (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 6-13).

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

Discharge sequence after power down

Hazardous voltages will remain on the controller internally and on exposed power terminals for a period of time after the main power connections have been removed.

Hazardous voltages may remain on the controller internally and on exposed power terminals after the main battery power connections and keyswitch power supplies have been removed if the controller is connected to a rotating permanent magnet motor.

Controller discharge profiles

The following graph shows the standard controller discharge curve which should be observed. This curve only applies if the discharge circuit in Main Contactor and Precharge circuit is not used or has been disconnected.

Do not open the unit or work near exposed power terminals until the voltage has reduced to a safe level.

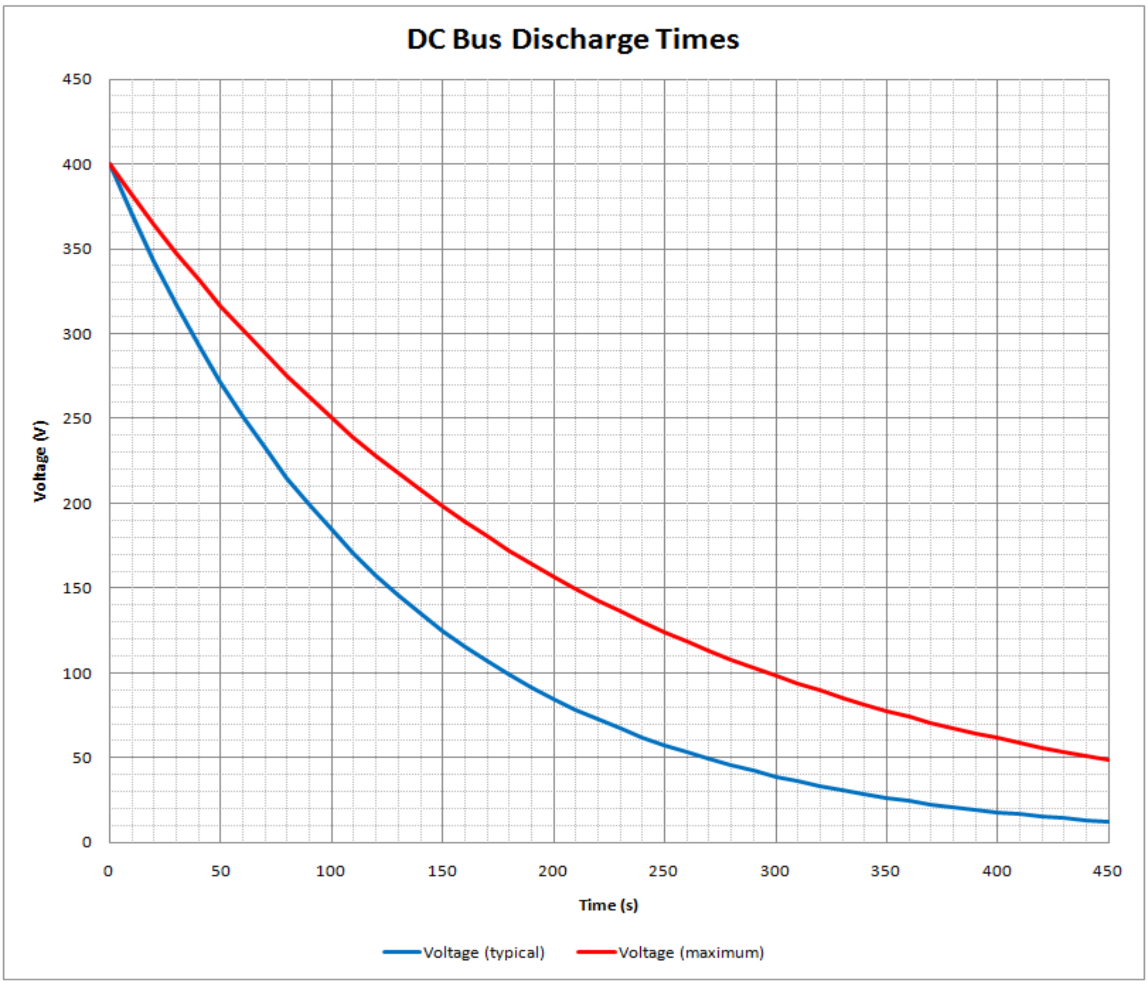

Figure 19: Standard discharge curve for the Gen4 Size 8 controller

To determine the required time, note the time at which the "Voltage (maximum)" curve crosses the horizontal gridline corresponding to the supply voltage. Then note the time at which it crosses the horizontal gridline corresponding to the safe voltage level (normally considered to be 60V). The difference between the two times is the safe discharge time period.

To achieve a shorter discharge time the vehicle system designer must ensure that the line contactor and capacitor precharge circuit also incorporates a discharge circuit which is activated once the main line contactor is openned.

If the controller is connected to a permanent magnet motor and the motor is rotating the discharge circuit will be exposed to the rectified back emf even if the controller keyswitch power supply is turned off.

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6 Chapter 6: Configuration

Introduction

This section covers what you need to do to configure Gen4 size 8's software once you have designed and installed your hardware. All of Gen4 size 8's parameters have a default value and the amount of configuration needed is dependent on your particular system.

The main topics are:

- DVT 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

DVT configuration tool

DVT is Sevcon's proprietary configuration tool. It allows the user to monitor, configure and duplicate the parameters of any Sevcon CANopen node such as the Gen4 Size 10 controller. The information presented here is an overview only. Contact Sevcon for more information about DVT and the functions it provides.

DVT functionality

DVT provides the following facilities:

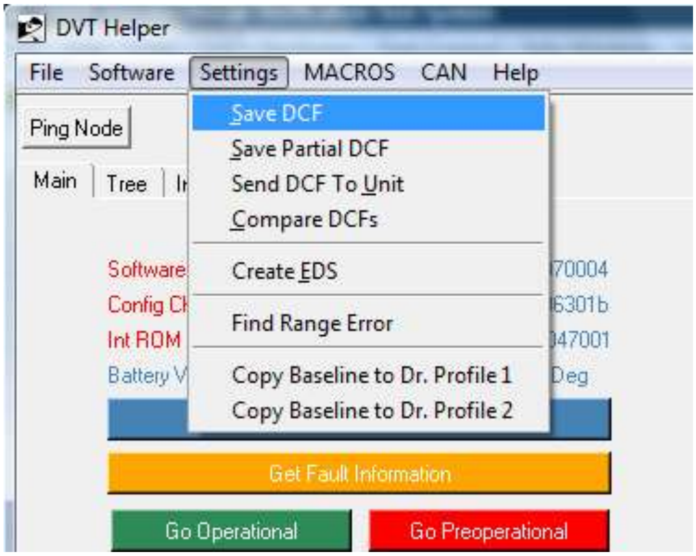
- Configuration of controller IO, CANBus, motor parameters & vehicle drive performance parameters
- Loading DCF configuration file into the Sevcon controller
- Saving of DCF configuration file from controller to file on computer
- Controller status and fault diagnosis
- Data logging of controller/motor performance on test bench or vehicle
- Update controller firmware

Saving, duplicating and restoring a node's configuration

You can use DVT 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.

For example, if you want to save the Gen4 Size 10 controller configuration, you will need to create a DCF file. To do this, open the helper by clicking the  icon at the top of the DVT main window.



Data Logging.

You can use DVT to monitor data or parameters of a Sevcon node in real time and graph the data.

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 size 8 controller.

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 size 8 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 size 8 controller by reading and writing values in its Object Dictionary, using a configuration tool such as Sevcon's DVT (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 DVT to describe the structure of a node's Object Dictionary. An EDS for each Gen4 size 8 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 size 8 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 size 8 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 DVT) or for accessing data at a very low rate.

PDO (Process Data Object)

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

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 baud rate in 5900_h to the required values. Node IDs must be unique, and the baud rate must be the same for each node.
2. Set SYNC COB-ID in 1005_h 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 1006_h.
3. Set the EMCY message COB-ID to 0x80 + node ID in 1014_h.

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

4. Configure the heartbeat producer rate in 1017_h. This is the rate at which this node will transmit heartbeat messages.
5. Configure the heartbeat consumer rate in 1016_h. 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 5901_h. 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 (1200_h) which is reserved for communication with configuration tools like DVT or the calibrator. Another 3 SDO servers can be configured at 1201_h to 1203_h. 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 1280_h to 1286_h. 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 2810_h.

Configure RPDOs (1400_h to $17FF_h$) and TPDOs (1800_h to $1BFF_h$) appropriately for the system. See section, Manual object mapping (page 6-11), for more information.
Configure the RPDO timeout function if required. See section PDO mapping (page 6-12) for more information.

3rd Party CANopen Devices

At power up, the Gen4 size 8 master will communicate with all slave nodes to identify which nodes are Sevcon devices and which are not using the vendor ID in 1018_h. This instructs the Gen4 size 8 how to handle EMCY messages from each node.

Gen4 size 8 knows how to react to EMCYs (faults) from Sevcon slaves and can take appropriate action. Gen4 size 8 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 2830_h.

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 DVT.

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	6-10
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 DVT, select User ID and password when prompted.

To login with other configuration tools write your password and, optionally, a user ID to object 5000_h 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 (5001_h).

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. DVT takes Gen4 size 8 in and out of this state as required.

If you are not using DVT 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 2800_h on the master node.

To restore the CANopen network to operational, write '0' to 2800_h.

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 5110_h where 05 = operational and 7F = pre-operational.

Motor characterization

Ensure you have completed the CANopen network setup process.

Determining induction motor parameters

To provide optimum motor performance Gen4 size 8 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 21.
- The magnetic saturation characteristics of the motor in the constant power and high speed regions.
- Current and speed control gains.

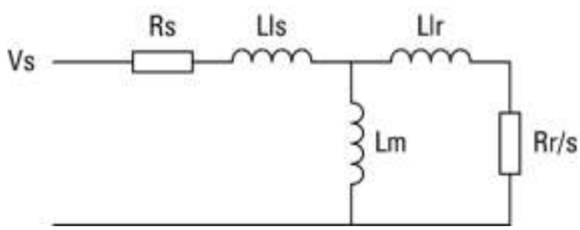


Figure 21 AC motor single-phase equivalent circuit

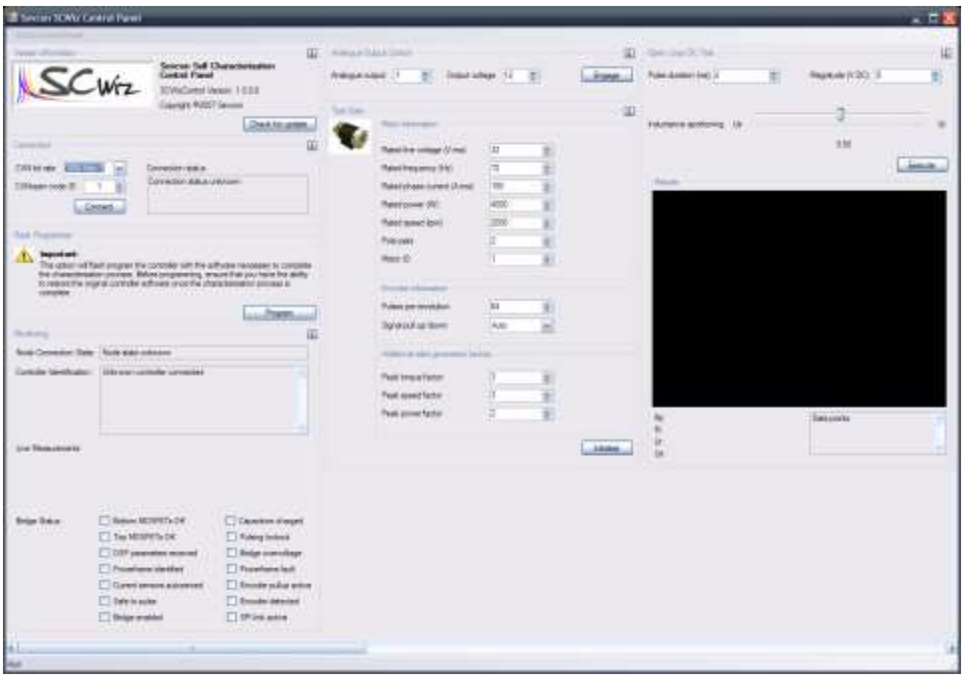
To determine these parameters use one of the following methods:

1. Ask the motor manufacturer to provide the data and enter it in the Object Dictionary at 4640_h and 4641_h. Also enter encoder data at 4630_h and 6090_h and motor maps at 4610_h to 4613_h.
2. Use the motor name plate data and the self characterization routine provided by Gen4 size 8 and DVT (described below).

Self characterization

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 size 8 controller connected to a PC or laptop running characterisation software. For further information, please contact your local Sevcon representative.



At time of writing, SCWiz is not yet compatible with Gen4 Size 8. Induction motor parameter characterisation therefore needs to be carried out using a lower voltage (48V or 80V) Gen4 controller.

Determining PMAC motor parameters

Gen4 size 8 supports both surface magnet and interior (buried) magnet types of PMAC motor. Motors which do not exhibit saliency (generally surface magnet motors) can be controlled via a standardised control scheme based on motor parameters. These are a subset of the induction motor parameters and are found in in the Object Dictionary at 4641_h. Motors which are salient require piece specific configuration which is only supported directly through Sevcon applications. Please contact Sevcon Applications for more detail.

The PMAC control functions are provided by a different build of software and although a large proportion of the functionality is consistent with induction machine control there are parameters, which are not necessary for PMAC configuration. Only the following are required, typically provided by the motor manufacturer.

Feature	Object indices	Notes
Current control gains	4641_h,13 4641_h,15 4641_h,33 4641_h,34	PI control gains for inner current control loops
Maximum stator current.	4641_h,2	Maximum stator current in Amps
Back EMF constant	4641_h,18	Back EMF constant of the motor in line to line RMS Volts per radian per second
Stator Inductance	4641_h,10	Phase inductance in Henries
Minimum field weakening current	4641_h,3	Minimum field weakening current in Amps
Stator Inductance	4641_h,10	Phase inductance in Henries
Maximum modulation index	4641_h,30	Maximum modulation index allowed during drive
Field weakening control gains	4641_h,25 4641_h,26	Tunable parameters to compensate for motor parameter inaccuracy during field weakening.
Power limit table.	4611_h	Static limit lookup table of maximum output torque with respect to motor speed.
Encoder Configuration	4630_h, 6090_h	Encoder configuration.

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 (2000_h to $24FF_h$) to the hardware I/O objects on all other nodes (6800_h to $6FFF_h$).

To configure I/O:

- Configure PDOs and VPDOs to map application objects on the vehicle master node to hardware I/O objects on other nodes
- Setup each hardware I/O object, including wire-off protection.

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 size 8 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 3000_h to $3FFF_h$ as shown in the table below. Use DVT, 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 22. 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.

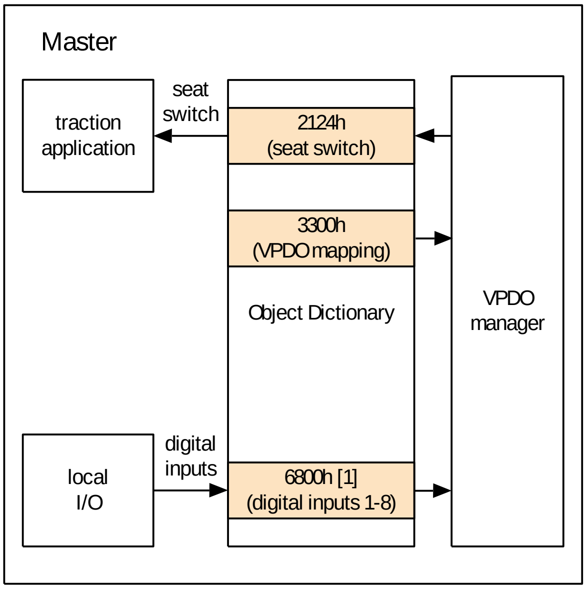


Figure 22 Example of a digital input mapped to the seat switch via VPDO

The number of sub-indices of each VPDO object depends on the amount of I/O on the device. For example, 3300_h 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 3300_h 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 6800_h,1), sub-index 4 of 3300_h would be set to 2124_h.

Some further examples are:

- Map FS1 to read the value of digital input 8 (connector A, pin 11): at 3300_h sub-index 8 enter the value 2123_h.
- Map the electromechanical brake signal to be applied to analog output 2 (customer connector, pin 7): at 3200_h sub-index 2 enter the value 2420_h.

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 (control word, target torque and target velocity) and some of which flow from local I/O to application (status word, 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 DVT. If you are using a 3rd party configuration tool, the relevant Object Dictionary indices are listed in Table 5.

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 5 Objects associated with mapping

An example mapping (Figure 23) 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.

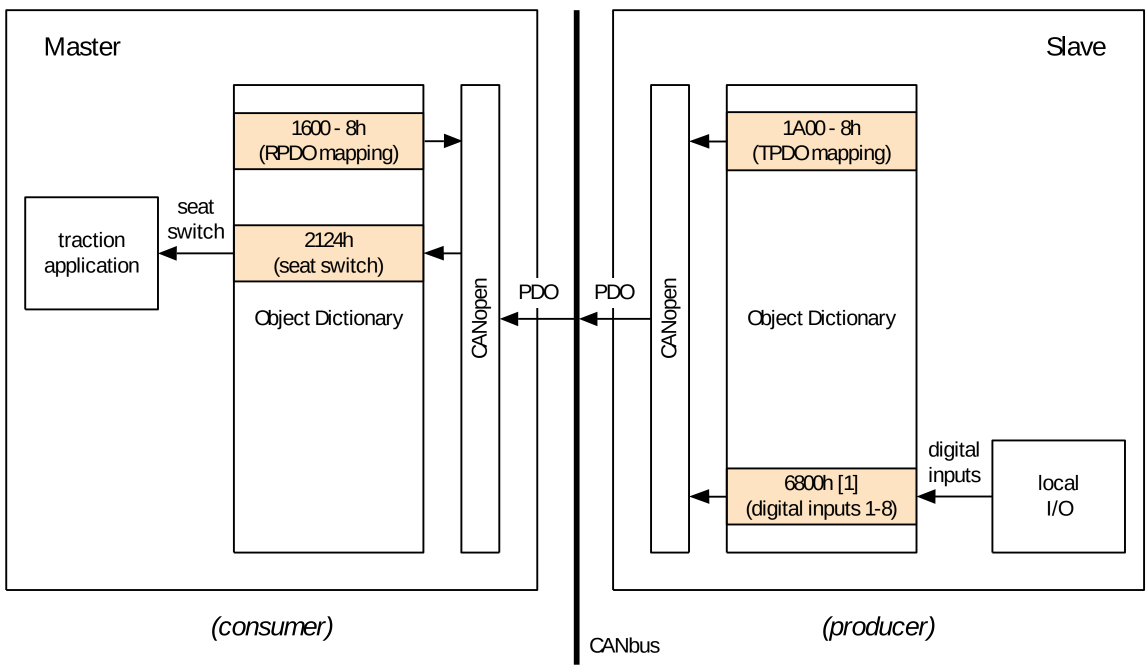


Figure 23 Example of a digital input mapped to the seat switch object via PDO and the CANbus

Gen4 size 8 supports RPDO timeout fault detection. This can set a warning, drive inhibit or severe fault depending on the configuration in 5902_h.

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

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. Configure the type of encoder: UVW, SinCos, single or multipole Resolver, AB, ABUVW or single channel.
2. Enter the resolution pulses/rev at 6090_h. (Note that if using a UVW or SinCos position sensor the ppr should be set to 64.)
3. Check whether the encoder requires controller pull ups enabled (e.g. open-collector type) and enable pull-ups if needed at 4630_h. The default setting is no pull-ups, which is suitable for current source encoder types.
4. Set the required encoder supply voltage (from 5V to 10V) at 4630_h.
5. If using a UVW, SinCos encoders or resolvers the Encoder Offset also needs to be configured in 4630h. This is stored in two parts and either can be used to define the offset. The first part gives +/- 127° to a resolution of 0.00390625 and the second gives +/- 1024° to a resolution of 0.0625. Both are stored at 4630h.
6. For SinCos encoders the minimum and maximum voltages for each channel and the number of waves per mechanical revolution also need to be configured.

Digital inputs

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

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 4680_h.
- Set digital input polarity at 6802_h. This is used to configure normally closed/open switches.

Analog inputs

The analog input voltages can be read at object $6C01_h$. 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.

There are 2 variable analog supplies at pins 29 and 30. Set the supply voltage at object 4693_h.

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

Name	Object	Pin	Usage
Analog Input 1 A	$6c01_h$,1	17	Input from external voltage source or 3-wire pot wiper. Use pin 29 as supply for 3-wire pot.
Analog Input 1 B	$6c01_h$,2	5	
Analog Input 2 A	$6c01_h$,3	18	Input from external voltage source or 3-wire pot wiper. Use pin 30 as supply for 3-wire pot.
Analog Input 2 B	$6c01_h$,4	6	
Motor thermistor	$6c01_h$,5	28	Use for motor thermistor input or 2-wire pot input. Has internal pull-up.

Wire-off detection

Enable wire-off detection at $46C0_h$ to $46C4_h$. 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 4620_h:

- Configure as none, switch or PTC thermistor
- For KTY84 thermistor, set the PTC type to KTY84.
- For non-KTY84 PTC thermistor, set the PTC type to User Defined and then set the expected voltages at 100°C (high temperature voltage) and 0°C (low temperature voltage). The Gen4 size 8 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 4600_h.

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 4690_h.

The digital input status object, 6800_h, 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

Do not use contactors which have built in 'economiser' circuits, the internal circuits are not compatible with the controller and may cause malfunction or damage. The same power reduction can be achieved with a standard coil by using the configurable pull-in and hold voltage settings.

There are 3 analog outputs which you may map to one or more contactor functions such as: 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 $46A1_h$.
  (At the time of writing, current controlled devices can only be operated from Gen4 size 8 by mapping a signal input to the controller from an external 3rd party node).
- Set the analog output values at object $6C11_h$. 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.

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 $6C43_h$ to use its last set value or the value at $6C44_h$ if the CANbus fails.
- Set values if needed at $6C44_h$ for each output. These values are 32-bit integers, but 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 $6C43_h$ and set the error value in $6C44_h$ 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 $6C43_h$.
- 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 $6C43_h$ and set the error value in $6C44_h$ to an appropriate voltage for the lamp.

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

Vehicle performance configuration

Ensure you have completed the CANopen network setup, Motor Characterization and I/O Configuration processes described above.

Safety Interlocks

FS1

The FS1 switch is normally part of the throttle assembly. It closes when the throttle is pressed. The throttle voltage is ignored until FS1 is closed.

FS1 features are configured at 2914_h:

- SRO (static return to off): inhibits drive if FS1 is closed for the SRO delay without any direction (forward or reverse) being selected.
- FS1 recycle: forces the operator to lift their foot off the throttle before allowing drive after a direction change.

Deadman

The deadman switch operates similar to the FS1 switch, whereby, it inhibits drive until it is active. However, the deadman switch applies the electro-mechanical brake immediately on deactivation, whereas FS1 waits for the vehicle to stop before applying the brake.

Seat

The seat switch indicates operator presence on the vehicle. Drive is not allowed if this switch is open. If the seat switch opens during drive for a period longer than the seat switch delay, a fault is set, disabling drive. To clear a seat fault, close the seat switch, open FS1 and deselect the forward/reverse switch.

Set the seat switch delay at object 2902_h.

Handbrake

If mapped to a digital input, the handbrake switch inhibits drive if the vehicle handbrake is applied. Controlled roll-off detection is still active when the handbrake is applied in case the brake fails.

Sequence Fault Masking

If an application does not require it, sequence fault checking can be disabled on selected drive inputs. This is set at 2918_h.

Similarly, drive inputs can be masked when clearing drive inhibit faults. This is set at $291A_h$.

These masks must only be applied if the application has other adequate means of protection. It is the responsibility of the installer to ensure this.

Torque mode/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.

The Gen4 size 8 controller provides both torque and speed control modes. Objects 2900_h and 6060_h are used to set which mode to use. The default setting is torque mode.

Always ensure 2900_h on the master node and 6060_h on all the traction nodes (master and slaves) match otherwise motor signals between the master and slaves may be misinterpreted.

The speed control (speed mode) or speed limit (torque mode) is controlled using PI loops. These loops are configured at 4651_h. The following parameters can be configured:

- Standard proportional and integral gains (4651_h, 1+2). Used to configure the loops during normal operation.
- Low speed proportional and integral gains (4651_h, 3+5). Used to configure the loops at low speeds (<50 RPM) and during hill hold. These are normally set lower than the standard gains to dampen oscillation as the vehicle comes to a stop.
- Roll back integral gain (4651_h, 4). Used to boost the integral term to prevent vehicle roll-off down inclines, particularly when Hill Hold is enabled. Normally, this gain is higher than the standard integral gain.
- dw/dt gain (4651_h, 6). Used to boost the torque output in speed mode, when a large increase in speed demand occurs. Not used in torque mode.
- Integral initialization factor (4651_h, 7). Used to initialize the integral term on entry to speed limit in torque mode. This factor is multiplied by the actual torque to set the integral term. Not used in speed mode.

These settings affect how driver demands are interpreted by the controller. In torque mode, the throttle push translates into a torque demand, which is applied to the traction motor. In speed mode, the throttle push translates to a speed demand. The controller then calculates the torque required to maintain this speed.

The difference between these control methods is most apparent when driving on an incline. In torque mode, when the vehicle is driven uphill, the vehicle speed will decrease due to the increased load. The operator must apply more throttle demand in order to maintain speed. In speed mode, the controller will apply additional torque in order to maintain the operator's speed demand, without the operator having to increase throttle demand.

Throttle

General

The controller can use 2 or 3 wire throttle inputs of the following types:

- Linear potentiometer in the range 470 Ω to 10 kΩ
- Voltage source in the range 0V to 10V: compliant with the standard 0..5 V, 0..10 V or 3.5..0 V ranges

To setup throttle inputs see 'Analog inputs' on page 6-14. The throttle voltage (2220_h) must be mapped to an analog input.

It is recommended that inputs with wire-off detection are used for the throttle input to detect wiring faults. This is especially important if a wire-off sets maximum throttle. See section Analog inputs (page 6-14) for more information.

Setup the characteristics of the throttle at 2910_h, sub-indices 2 to 20.

- Define the throttle voltage input: this is the relationship between the throttle voltage and the throttle value. Separate relationships can be specified for forward and reverse. Each relationship has two points, a start and an end. The points are configured differently for standard and directional throttles as shown in Figure 24 and Figure 25 respectively.

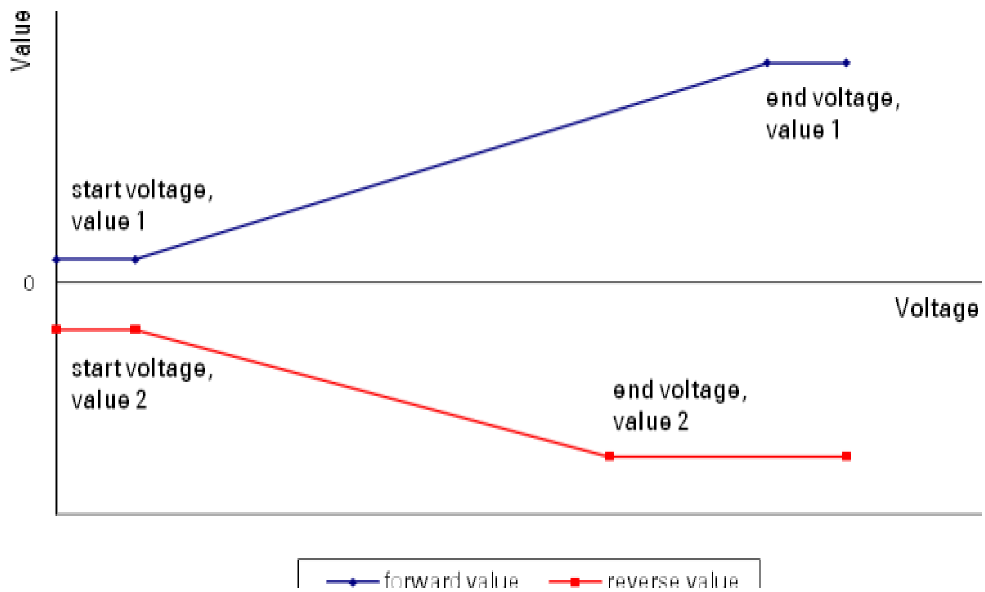


Figure 24 Standard throttle configuration

If the reverse characteristic is the same as the forward characteristic, just set all the reverse throttle parameters to 0 in 2910_h.

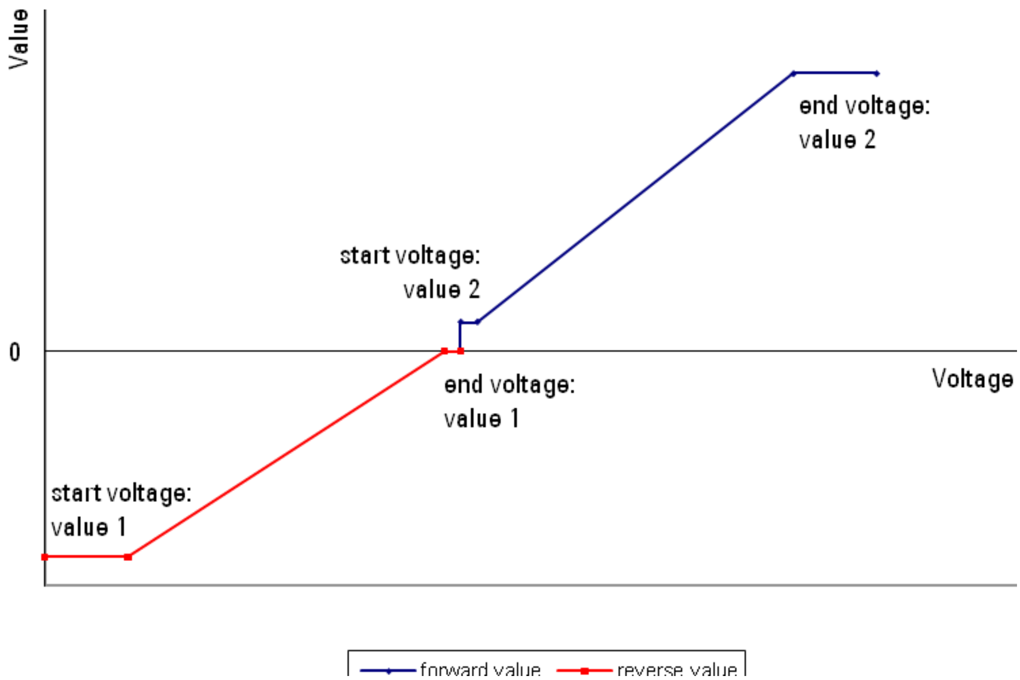


Figure 25 Directional throttle configuration

- Define the input characteristic: this is a profile to the throttle value and can be linear, curved, crawl or user-defined as shown in Figure 26. The curved and crawl characteristics give greater throttle control at low speeds.

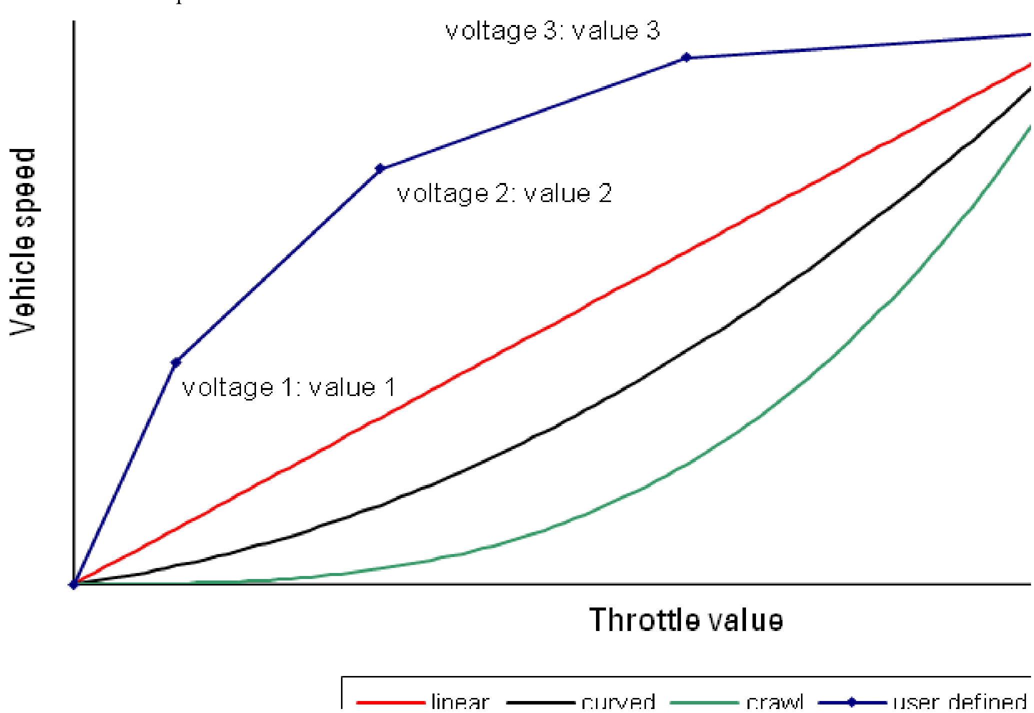


Figure 26 Input characteristics

The throttle value calculated from the voltage can be read at 2620_h.

Dual Throttle Inputs

Single and dual throttle inputs are supported.

Single throttle inputs are normally used with other interlock inputs (eg FS1, deadman, etc) and use a single input voltage to determine driver demand.

Dual throttle inputs use two separate input voltages, each of which is converted to a throttle value using 2910_h, subindices 3 to 6 (throttle input 1) and subindices 7 to 10 (throttle input 2). If the throttle values differ by more than 5%, a throttle fault is set and the system will not drive.

To enable dual throttle functionality, map a second analog input to 2224_h. The throttle value for the second throttle input can be read at 2626_h.

Dual throttle systems allow a virtual FS1 feature, which can be used instead of an actual FS1 switch. This feature can be enabled on dual throttle systems using 2910_h, 1.

The voltage input characteristics of the two analogue throttle inputs must be different.

Creep Torque

Creep torque allows a small amount of torque to be applied as soon as the throttle is closed. This can be used on some vehicles to overcome the friction required to achieve initial vehicle movement.

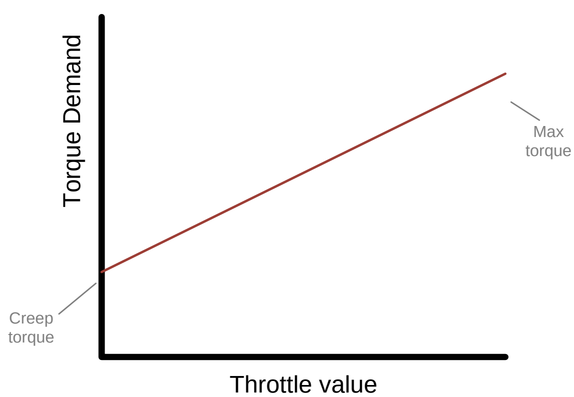


Figure 27 - Illustration showing behaviour of creep torque

Increasing the creep torque level can improve how the vehicle feels when drive is first selected and the vehicle starts to move. However, too much creep torque can make the vehicle uncontrollable at low speeds.

Creep torque will be applied as soon as drive is selected and the throttle is closed. Do not increase the creep torque value to a level that would cause unexpected high levels of torque output for comparatively low levels of throttle push. If in doubt, set the creep torque level to 0%.

Driveability Features

These features are used to configure how the system uses throttle information and how it handles speed limits (in torque mode). The installer must ensure these features are configured appropriately.

Set the following driveability features at 2910_h,1:

- Enable/disable proportional braking. If enabled, the braking torque during direction braking is proportional to the throttle.
- Enable/disable directional throttle. If configured as a directional throttle, the throttle voltage indicates the direction as well as the speed demand. This removes the need for forward and reverse direction switches.
- Proportional speed limit enable/disable. If enabled, speed limit is proportional to the throttle, otherwise speed limit is fixed at the forward or reverse maximum speed. Only used in torque mode.

Proportional Speed Limit 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.

- Braking directional throttle enable/disable. If enabled, a directional throttle can be used to demand a drive or braking torque in conjunction with the direction switches. Only used in torque mode.
- Reverse speed limit encoding. Controls how reverse speed limits are handled in torque mode. Must always be enabled on Slip control systems, and must always be disabled on flux vector and PMAC systems.
- Handbrake fault. If enabled, a handbrake fault is set when a direction is selected whilst the handbrake input is active.
- Proportional speed limit during braking enable/disable. If enabled, speed limit is proportional to throttle only in drive states. Maximum speed limit is allowed in braking states. Only used in torque mode.
- Driveability Consolidation. Normally, driveability profiles are only used to reduce vehicle performance, however, if this is enabled, an active driveability profiles over-writes the baseline. This allows vehicle performance to increase when a profile is active. Note, that this feature is not available in all software builds.
- Allow step change in steering angle. If enabled, steering angle can change instantly with steering voltage. If disabled, steering angle is rate limited to 90°/s which prevents sudden steering angle changes in the event of a steering sensor wire-off.
- Virtual FS1 enable/disable. If enabled, this sets up a virtual FS1 feature on systems with dual throttle inputs configured.

An s-curve profile can be applied to the speed target (in speed mode) or maximum speed (in torque mode). This can be set at $290A_h$.

Acceleration and braking

See 'Driveability profiles' for more information on page 6-25.

Some vehicles can exhibit shock due to the rapid reversal of torque after a direction change. 2909_h can be set to force the vehicle to remain stationary for a period before driving in the new direction.

To prevent early exit from neutral braking, a debounce timer can be set at $290D_h$. Neutral braking only finishes when the vehicle has been stopped for longer than this time. This can help prevent early exit of neutral braking due to motor oscillation caused by under damped suspension.

On vehicles with gearbox meshing issues, a slower rate of torque ramp up at low speeds can be configured at $291C_h$. This slow rate of change of torque lessens shock due to gear meshing. Used in torque mode only.

Brake feathering reduces neutral and foot braking torques as the vehicle speed approaches 0 to prevent any roll-back in the opposite direction. This is set at $290E_h$. Used in torque mode only.

Footbrake

The controller can use a switch or analog voltage as the footbrake input. If a footbrake switch is mapped, it applies maximum foot braking when the switch is closed. The footbrake switch object (2130_h) must be mapped to a digital input.

If the footbrake input is an analog voltage, configure the voltage levels in the same way as the throttle. The footbrake voltage (2221_h) must be mapped to an analog input.

Configure the characteristics of the footbrake at 2911_h:

- Drive/foot braking priority. If the throttle and footbrake are pressed at the same time, this setting determines whether the system attempts to drive or brake.
- Minimum speed for braking. Foot braking stops when the vehicle speed drops below this level.
- Footbrake voltage input and Input characteristic. These settings are similar to those for the throttle. Refer to the Throttle section above for more information.

The footbrake value calculated from the voltage can be read at 2621_h.

Steering inputs – twin driving motor systems

Loss of steering information can make a vehicle operate erratically. The analog input use for the steering sensor should have suitable wire-off protection configured.

Twin motor systems, which use the drive motors for turning, require some means of determining the angle of the steering wheel.

To do this use one of these options:

- A steering potentiometer to give an analog voltage which is a linear function of the steering angle. The steer potentiometer voltage (2223_h) must be mapped to an analog input.
- Four digital inputs representing 'inner left', 'inner right', 'outer left' and 'outer right'. The inner switches indicate the steering angle where torque to the inner wheel motor is removed. The outer switches indicate the steering angle where inner wheel motor changes direction. The outer switches are optional. The steer switches ($212B_h$ to $212E_h$) must be mapped to digital inputs.
- Steering angle from 3rd party CAN device. This can be received via RPDO on object 2624_h in 0.01°/bit resolution.

To configure steering inputs go to index 2913_h in the Object Dictionary:

- Setup the voltages corresponding to fully left, fully right and straight ahead. Using this information, Gen4 size 8 calculates the steering angle based on the voltage from a steering potentiometer.
- Setup the steering map. This map defines the relationship between the inner and outer wheel speeds and the steering angle. Each map has 4 user definable points as shown in Figure 28.

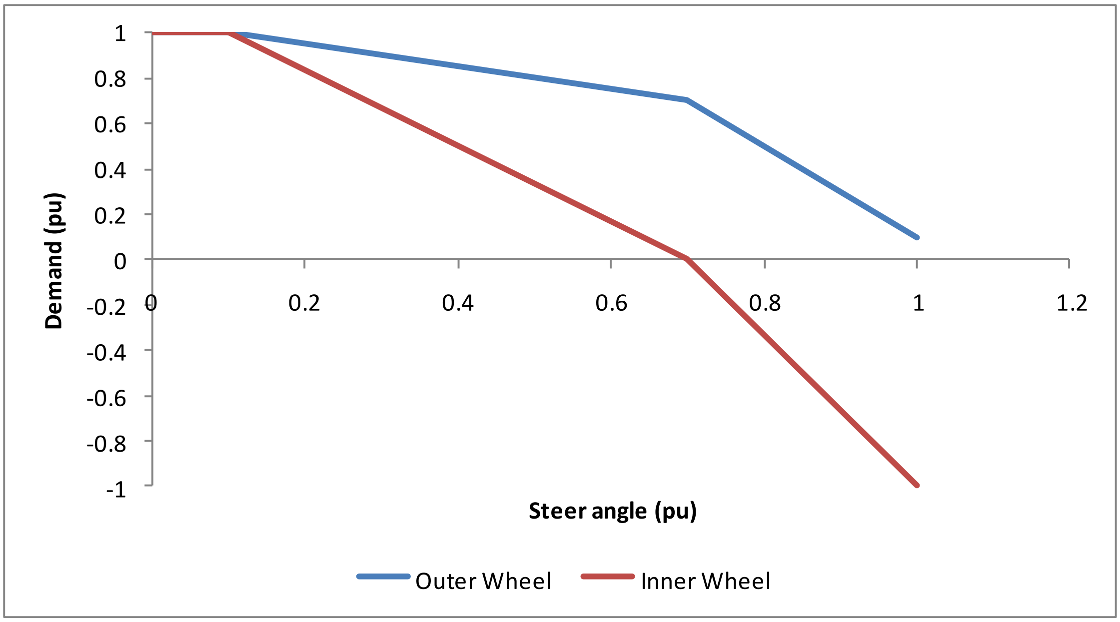


Figure 28 Graph of speed vs. steering angle

The speed and steering angle are normalized. Speed is normalized to maximum vehicle speed and the steering angle to 90°.

In speed mode, outer wheel speed target and maximum torque is scaled according the outer wheel map. Inner wheel speed target and maximum torque is scaled to the outer wheel demands according to the inner wheel map.

In torque mode, both inner and outer wheel maximum speeds are scaled according the outer wheel map. The outer wheel target torque comes from the throttle. The inner wheel target torque is scaled to the outer wheel actual torque according the inner wheel map.

In object 2913_h, 0 to 1 is represented by values in the range 0 to 32767. The inner wheel is scaled according to the outer wheel. Where a demand (pu) of -1 is shown at 90° for the inner wheel, this means the inner wheel demand will be equal and opposite to the outer wheel.

The calculated steering angle can be read at 2623_h. An angle value of -32767 indicates full steering to the left, +32767 full steering to the right and 0 is straight ahead.

If steering switches are used instead of a steering potentiometer, only part of the steering map is used as shown in Table 6.

Value	Description
2913_h,9	Outer wheel speed during inner wheel cutback
2913_h,11	Outer wheel speed during inner wheel reversal
2913_h,17	Inner wheel cutback speed
2913_h,19	Inner wheel reverse speed

Table 6 Objects to set when using steering switches

During a turn the inner wheel speed is slowed by power reduction instead of braking to prevent the outer wheel motor working against the inner wheel motor.

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Driveability profiles

Ensure driveability profiles are disabled when not required. Activation of a driveability profile can cause driving parameters to change.

Driveability profiles allow you to set maximum values for speed, torque, acceleration and deceleration for use in a range of operational situations. In addition, in torque mode, there are ramp rates for speed limits as well. **Error! Reference source not found.** and Figure 30 show the change in speed and torque target under various driving conditions over a period of time.

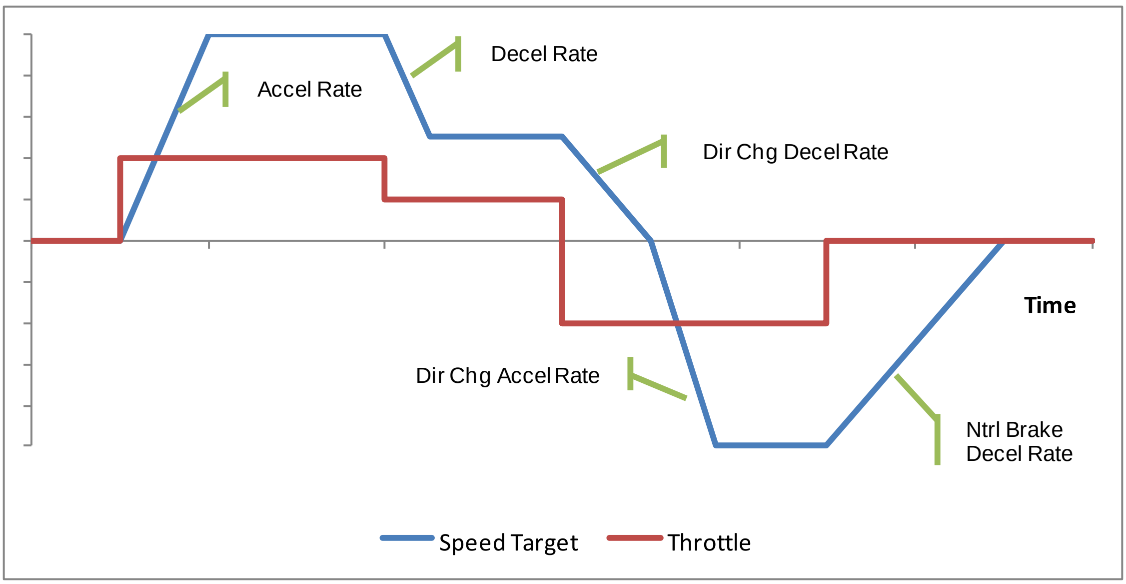

Figure 29 Speed mode acceleration/deceleration

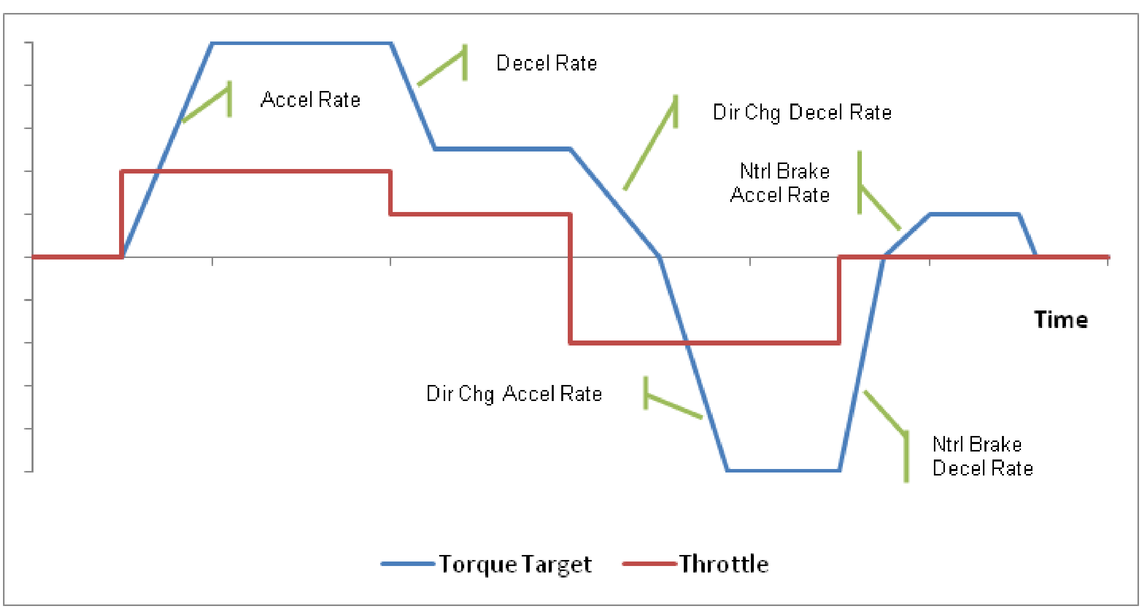

Figure 30 Torque mode acceleration/deceleration

In Torque mode, the acceleration and deceleration rates control the rate of change of torque. In Speed mode, the acceleration and deceleration rates control the rate of change of speed.

You can select reverse while driving in the forward direction with your foot still on the throttle. In this situation the controller applies braking in the form of a direction change deceleration rate down to zero speed. It then applies a direction change acceleration rate to increase the vehicle's speed in the reverse direction up to the set maximum speed as shown above.

Configure the following drivability profiles to suit your application (each containing the same set of parameters):

- Traction baseline profile: the default and highest set of values (2920_h).
- Drivability select 1 profile: invoked when drivability select 1 switch is active (2921_h) or an alternative trigger is active (see below).
- Drivability select 2 profile: invoked when drivability select 2 switch is active (2922_h) or an alternative trigger is active (see below).

The traction baseline profile contains the default maximum values. All of the remaining profiles apply lower, modifying values to the baseline profile. BDI and service profiles, when configured, are automatically applied by the software under preset conditions. For example you may want to limit the acceleration and maximum speed of a vehicle when the battery gets low to maximize the operating time before recharge. The remaining profiles are applied by the driver with a switch.

Drivability profiles can also be invoked by internal software triggers, such as BDI low, service required or low speed. These can be selected to suit specific application requirements. Set the profile triggers in 2931_h.

Where more than one profile is active, the lowest value(s) are used by the software.

Speeds in driveability profiles are scaled according to the vehicle gear ratio (2915_h). This is used to convert speed in RPM to any other preferred unit such as KPH or MPH. To remove this scaling and leave driveability profile speeds in RPM, set 2915_h,3 to 1.

Torques in driveability profiles are in 0.1%/bit resolution. These are converted to Nm using the motor rated torque value at object 6076_h.

Ramp rates in driveability profiles are in either RPM/s for speed mode, or %/s for torque mode. In speed mode, RPM/s becomes "User Defined Units" / s if the gear ratio is used to rescale the driveability profile speeds.

Speed limit ramp rates are only used in torque mode and are in RPM/s (or user defined units / s).

In addition to the speed limit ramp rates in the profiles, $291E_h$ can be used to configure safety limits on speed limit ramping. The installer should set these ramp rates to suitable levels to ensure speed limits cannot ramp faster than could actually happen on a vehicle. This can protect against harsh braking if traction wheels are momentarily locked.

Preventing Wheel Lock Scenarios

For certain vehicle types, particularly on-highway vehicles or electric motorcycles, the possibility of wheel locking during drive must be considered.

During braking, the controller will maintain a speed limit to ensure the vehicle does not over speed if entering braking whilst travelling downhill. If proportional speed limit is set then the speed limit will follow actual speed toward zero whenever actual speed is dropping rapidly, usually due to some external influence such as application of mechanical brakes.

If the brakes are applied too harshly, then there is possibility to lock the drive wheels. In these circumstances, the normal reaction of the driver is to release the brake to allow the wheels to rotate again. The correct operation of the controller in this scenario is to allow the wheels to continue to rotate, and not impose a speed limit.

The maximum rate at which the speed limit can increase or decrease is specified in object 291E $_h$. By limiting the rate at which the speed limit can decrease, we can ensure that if the brakes are released after they had locked the drive wheels, the controller's speed limit will allow them to rotate again. The operation of this is shown in Figure 31 below.

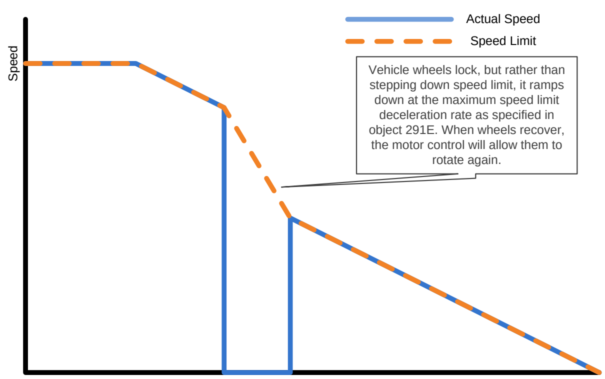

Figure 31 - Example of behaviour of speed limit when drive wheels are locked

It is important to consider the behaviour of the vehicle under all drive conditions, including when traction is lost due to locking of the drive wheels. When testing a vehicle, check that the vehicle behaves in a safe manner when performing harsh braking on low-friction surfaces such as gravel.

Controlled roll-off

Controlled Roll-Off 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.

Controlled roll-off limits a vehicle to a slow, safe speed if it starts to move without any operator input. Primarily, it is to prevent uncontrolled movement if a vehicle's brakes fail on an incline. Controlled roll-off operates whether the operator is present or not.

Configure the following at object 2930$_h$:

- Enable/disable controlled roll-off
- Set a roll-off maximum speed
- Set a roll-off maximum torque

Alternatively, Gen4 size 8 can apply an electromagnetic brake if one is mapped and roll-off is detected. Refer to 'Electro-mechanical brake' on page 6-32 for more information.

Hill hold

Hill Hold 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.

A vehicle on a hill can be held at a standstill for a configurable time when the operator selects neutral. At the end of this time or if the seat switch indicates the operator is not present, hill hold terminates and the vehicle can start to move if parked on an incline. If enabled, the system will enter controlled roll-off after hill hold.

You can set the hill hold delay at object 2901_h. Set the hill hold delay to 0 to disable this feature.

In speed mode, drive torque is disabled whilst neutral braking to stop. However, drive torque must be re-enabled when entering Hill Hold to allow torque to be applied to hold on the incline. Set the speed to re-enable drive torque at 2908_h.

Inching

Ensure inch switches are only mapped to digital inputs when required. Activation of these inputs can cause a drive condition to occur.

Inching allows an operator to manoeuvre a vehicle, at low speeds, towards a load. Inching can be initiated with one switch. A time-out is used to prevent the vehicle from continuing to drive indefinitely if the switch gets stuck or goes short circuit.

To configure inching:

- Ensure forward and reverse inching switches have been mapped to two digital inputs.
- Specify an inching speed (0% to 25% of the full speed of the vehicle) at 2905_h sub-index 1. This is either a speed target in speed mode, or maximum speed in torque mode.
- Specify an inching throttle (0 to 100%) at 2905_h sub-index 3. This gives a torque target in torque mode. This is not used in speed mode.
- Specify a time-out (0.1 s to 5.0 s) at 2905_h sub-index 2.

Belly Switch

Ensure the belly switch is only mapped to a digital input when required. Activation of this input can cause a drive condition to occur.

The belly switch is normally connected to the end of the tiller arm on class 3 vehicles. When activated it forces a drive condition in forward at a user specified throttle value and maximum speed for a specified time.

To configure belly:

- Ensure the belly switch is mapped to a digital input.
- Specify the maximum belly speed at $290C_h$ sub-index 2.
- Specify a belly throttle at $290C_h$ sub-index 1. This will determine the torque demand in torque mode or speed demand in speed mode.
- Specify a belly time out at $290C_h$ sub-index 3. The belly function will cease after this time has expired.

Drivability select switches

Ensure the driveability switches are only mapped to digital inputs when required. Activation of these inputs can cause driving parameters to change.

There are two drivability select switches (2126_h and 2127_h).

To enable either of these they must be mapped to digital inputs. When they are active, the corresponding drivability profiles (2921_h and 2922_h) are applied.

See Driveability profiles (page 6-25) for more information.

Economy

The economy input is an analog input which can be used to increase vehicle efficiency and extend battery life. It is normally controlled using a potentiometer mounted on the vehicle's dashboard. The economy voltage (2222_h) must be mapped to an analog input.

Efficiency is improved by reducing the acceleration rate or the maximum torque.

Configure the economy input at object 2912_h as follows:

- Economy function: select acceleration or torque.
- Economy voltage input: These settings are similar to those for the throttle (see page 6-18).

The economy value calculated from the voltage can be read at 2622_h.

Pump configuration

The controller can use a mixture of switch and analog voltages as the pump input. In addition, the power steer function can be used as an extra input to the pump if the pump motor is required to supply pump and power steering.

Pump motors always run in speed mode. Ensure the motor slave is also configured for speed mode in 6060_h.

General Setup

Configure the pump features at $2A00_h$:

- Inhibit pump when BDI drops below cut-out level. If already operating when the cut-out occurs, the pump will continue to operate until all pump inputs are inactive.
- Drive Enable switch and/or Seat switch input disables pump.
- Ignore Line Contactor state. Allows the pump to operate if it is not connected to the battery through the line contactor. Should be set if the pump also supplies power steering and the power steer is required to operate when the line contactor is open.
- Use Power Steer target velocity as pump input, if pump also supplies power steering.
- Enable minimum pump speed. Enable this to force the pump to run at minimum speed ($2A01_h$, 2) even when there is no trigger. Can be used to maintain minimum pump pressure.
- Pump to stop on Low Battery. Enable to force pump to stop immediately on low battery condition.
- Use power steer demand to minimum pump speed. Enable this to force the pump to use power steer demand as a minimum speed. Can be used to maintain minimum pump pressure for power steering.

Set the pump minimum and maximum speed, maximum torque, acceleration and deceleration at $2A01_h$. The pump speed is calculated as the value from the inputs multiplied by the maximum speed.

Priority/additive inputs

Each pump input can be configured as a priority input or an additive input. When calculating the pump demand, the controller selects the demand from the highest priority active input, and then adds the demand from all the active additive inputs.

Configure priority/additive levels in $2A10_h$ and $2A11_h$, and $2A20_h$ to $2A26_h$.

Pump throttles

There are 2 pump throttle inputs, which can be configured independently at $2A10_h$ and $2A11_h$. The pump throttles allow proportional control of the pump speed.

Configure inputs as priority or additive and set the voltage levels in the same way as the traction throttle. The pump throttles must be mapped to analog inputs.

Pump switches

There are 7 pump switch inputs. Configure each input as priority or additive and assign it a value at $2A20_h$ to $2A26_h$. The pump switches must be mapped to digital inputs.

Pump Driveability Profiles

Pumps have configurable driveability profiles. Profiles are triggered by pump driveability select switches (2152_h and 2153_h). One or more of these switches must be mapped to enable pump profiles.

Each profile allows the installer to reduce acceleration and deceleration rates, throttle and switch values and maximum torque.

Set pump driveability profiles at $2A30_h$ and $2A31_h$

Power steer configuration

General

Power steering can be provided using:

- Contactor. Map the power steer contactor drive object to an analog output.
- Pump motor controller. Configure pump to provide power steering. Power steer demand is added to pump demand.
- Dedicated motor controller. Map power steer application motor object to motor control slave.

Power steer motors always run in speed mode. Ensure the motor slave is also configured for speed mode in 6060_h.

The power steer can be triggered by a number of events:

- Vehicle moving
- FS1 switch activating
- Direction selected.
- Seat switch activating
- Footbrake activating

The power steering function will always attempt to execute, even if the line contactor is open due to a fault condition. This is to ensure power steering continues to operate at all times.

Set the power steer motor speed, acceleration and deceleration at $2B01_h$. This is not required if the power steer motor is operated by a contactor.

Variable Assist Power Steering

Gen4 size 8 supports a variable assist power steering algorithm which can be used to reduce the power steering speed as vehicle traction speed increases to a user configurable level. Set the reduction factor and traction speed in $2B02_h$. This allows power steering effort to be reduced as vehicle speed increases to prevent steering becoming too light.

Vehicle features and functions

Ensure you have completed the CANopen network setup, Motor Characterization, I/O Configuration and Vehicle Performance Configuration processes described above.

Contactors

Ensure voltage control has been selected (see ‘Analog (contactor) outputs’ on page 6-15).

To configure any contactor:

- Set pull-in voltage, pull-in time and hold-in voltage at $2D00_h$
- Enable each output to operate at the pull-in voltage or at the maximum voltage at $2D01_h$
- If required enable each output to reduce to the hold voltage level at $2D02_h$

Line contactor

Gen4 size 8 does not support line contactor or precharge functionality. An external device must be used to isolate the Gen4 size 8 from the vehicle battery. This external device is also responsible for any capacitor precharging required to prevent damage to the line contactor tips.

Electro-mechanical brake

Electro-mechanical brakes are not recommended for on-highway vehicles as they 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. Also, electro-mechanical brakes normally fail to the applied state, meaning any loss of power, or wiring fault can cause the brakes to be applied.

The electro-mechanical brake object (2420_h) must be mapped to an analog output.

Set the conditions under which it is applied at 2903_h.

The brake can be applied when the vehicle stops or when roll-off is detected. If the brake is configured to apply when the vehicle stops, it is not applied until the vehicle has been stationary for more than the brake delay time.

To prevent vehicle roll away on inclines, the electro-mechanical brake normally does not release until the traction motor(s) are producing torque. This feature can be disabled using 2903_h,3.

External LED

This mirrors the operation of the controller’s on board diagnostic LED. The external LED object 2401_h can be mapped to an analog output to drive a lamp on a vehicle dashboard.

Alarm buzzer

The alarm buzzer object (2402_h) must be mapped to an analog output.

Configure the alarm buzzer output, if required, to be activated by one or more of these conditions at 2840_h:

- forward motion or forward direction selected
- reverse motion or reverse direction selected

- faults other than information faults
- controlled roll-off
- BDI low.

A different cadence for each of the above conditions can be configured.

Brake Lights

A brake light output object is available (2404_h) and can be mapped to an analog output. The brake lights will illuminate whenever the footbrake is pressed (providing either an analog or digital footbrake input is available) or the system is in direction change braking.

Horn

Ensure a digital input switch is mapped to the horn switch object (2101_h) and an analog output is mapped to the horn object (2403_h).

Service indication

The controller can reduce vehicle performance and indicate to the operator when a vehicle service is required. The interval between services is user-configurable.

Configure the following at object 2850_h:

- Service indication: via an analog (contactor) output (e.g. to drive a dashboard lamp) and/or Gen4 size 8's LED.
- Source hours counter: selects the hours counter and is used to determine when a service is required.
- Service interval: hours between vehicle services. Can be used by the reset function (see below) or for information only.
- Next service due: Servicing is required when the source-hours counter reaches this time. This can be set manually, or automatically using the reset function; see below.
- Reset function: write to the reset sub-index at 2850_h to automatically reset the service timer for the next service. The next service due time is calculated as the source hours counter time plus the service interval.

Service profile

This is a drivability profile where you can set maximum torques, speeds and acceleration rates to be applied when a vehicle needs servicing (2925_h). See 'Driveability profiles' on page 6-25.

Traction motor cooling fan

This object can be used to drive a motor cooling fan when the operator is present on the vehicle (as indicated by the seat switch). The cooling fan object (2421_h) must be mapped to an analog output.

Controller heatsink fan

A controller offers the option of heatsink fans to cool the heatsink instead of liquid cooling.

The temperature at which the heatsink fans turn on and off are configurable. The fans will be turned on by the controller when the heatsink temperature exceeds a specified temperature. The fans turn off when the temperature is cold. The temperatures at which the fans turn on and off, is programmed using the internal heatsink fan object ($5A02_h$).

The temperature set-point to turn on the fans should be higher than the set-point to turn off the fans

The heatsink fans can be configured in $5A02_h$ to output a warning fault if the fans stop rotating.

Controller external heatsink / motor cooling fan

An external fan to cool the controller heatsink or a motor may be connected to one of the analogue outputs. The fan will be turned on by the controller when either the heatsink temperature or the motor temperature exceed a specified temperature. The fan turns off when the nominated temperature is cold. The temperatures at which the fans should turn on and off, the analogue output to use for the fan, the fan voltage and the temperature source (heatsink or motor) can be programmed using the external heatsink fan object ($5A01_h$). Note that the contactor driver outputs may be damaged if connected to capacitive loads. It is quite common for fans to incorporate capacitive elements, in which case a relay should be used to isolate the fan from the contactor driver output.

The temperature set-point to turn on the fans should be higher than the set-point to turn off the fans

The fans will not operate if another function is configured to run on the specified analogue output.

Motor over-temperature protection

The controller protects motors from over-temperature. It maintains a motor temperature estimate and can also accept a direct temperature measurement via an analog input (for a thermistor) or a digital input (for an over-temperature switch).

The temperature estimate is calculated by monitoring current to the motor over time. The estimate is configured at 4621_h.

The estimate is always applied, since it can detect increases in motor temperature more quickly than the direct measurement. Direct measurement is normally done on the motor casing, which lags behind the internal temperature.

Motor over-speed protection

A facility to protect the motor or vehicle power train due to damage by over speeding is available on the controller. A maximum speed can be configured at object 4624_h. Under normal operation the controller should output braking torque to prevent the over speeding initially, if the measured speed exceeds this limit then the controller will shut down and a fault will be set.

The trip speed offers a final level of protection for the vehicle mechanics, and should be set to a level that would not be expected to be reached under normal operation.

Battery protection

The nominal battery voltage must be set at $2C00_h$.

Over voltage

Battery over voltage usually occurs during regenerative braking.

To provide protection set values for these parameters at $2C01_h$:

- Over voltage start cutback: the value at which the braking effort is linearly reduced to limit voltage increase.

- Over voltage limit: the value at which the controller cuts out. A fault is set if the voltage exceeds the cut-out voltage.

Under voltage

To prevent excessive battery discharge, set values for these parameters at $2C02_h$:

- Under voltage start cutback: the value at which the current drawn from the battery is reduced to limit voltage decrease.
- Under voltage limit: the value at which the controller cuts out. A fault is set if the voltage drops below the cut-out voltage for longer than the protection delay
- Protection delay: the time it takes for the controller to cut-out after the under voltage limit has been reached (2C03h).

Battery Discharge Indicator (BDI)

CAUTION: When not in use ensure the BDI function is disabled by setting the Cell Count (in $2C30_h$, 6) to 0.

Monitor battery voltage using Gen4 size 8's Battery Discharge Indicator (BDI). The BDI presents the driver with a percentage remaining charge figure and has become an industry standard in recent years.

The BDI is not a measure of the absolute battery charge remaining and therefore we recommend you regularly check the absolute value in accordance with the battery manufacturer's instructions.

To use the BDI, configure the following parameters at $2C30_h$ in the Object Dictionary:

- Cell count: this is the number of battery cells and is normally half the battery voltage, as cells are usually 2 volts each.
- Reset voltage (V): set this to the cell voltage when the batteries have just been charged. This resets the BDI back to 100%.
- Discharge voltage (V): set this to the cell voltage when the battery is discharged.
- Cut-out level (%): this is the level at which the vehicle adopts the low battery drivability profile.
- Discharge rate (s/%): this is the rate at which the BDI remaining charge value discharges. Set to 0 to use default value of 16.8s to reduce by 1%. This default should suit most lead-acid battery types, however, this can be increased/decreased for different battery technologies.

Setting the warning and cut-out levels to 0% disables the warning and cut-out functionality

Read the percentage remaining charge value from 2790_h sub-index 1 in the Object Dictionary.

Battery Current Limit

Battery current can be limited by the controller for the purposes of efficiency or to protect batteries that are sensitive to high levels of current flow. Charge and discharge currents can be limited independently.

If limiting the discharge current flow, this can extend the time taken for the vehicle to reach top speed. Note that limiting the charge current flow back to the battery can impede the performance of regenerative braking.

Compatibility with some CAN based battery management systems is provided. It is also possible to configure different discharge limits for each driveability profile. The behaviour of battery current limit can be configured using object 2870_h. Object 4623_h shows the current limits that are in effect, and allows you to specify the cutback aggressiveness and a measurement correction factor. Battery current flow can be monitored at object 5100_h.

Note that regen currents flowing back to the battery are specified as negative numbers.

Displays

Gen4 size 8 is compatible with Smartview and Clearview displays.

Clearview displays use the CANopen protocol. To use, set up TPDOs to transmit the required data for the display.

Smartview displays use Sevcon's proprietary CAN protocol. To use set the CAN baud rate to 100kHz at 5900_h, enable Smartview and select hours counter at $2E00_h$.

7 Chapter 7: Monitoring Gen4 size 8

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Reading status variables

All status variables are in Gen4 size 8's object dictionary. They can be accessed using SDOs. Some can be mapped to PDOs for continuous transmission to remote nodes such as displays and logging devices.

Motor measurements

The following status objects can be read:

- Motor slip frequency, currents, voltages and temperature at object 4600_h.
- Additional motor debug information is available at 4602_h.
- Motor torque, speed, etc. at objects 6000_h to $67FF_h$.

Heatsink temperature

Read the heatsink temperature at object 5100_h, sub-index 3.

Identification and version

Read identification and version information at:

- 1008_h – Controller name.
- 1009_h – Hardware version.
- $100A_h$ – Software version.
- 1018_h – Identity object. Contains CANopen vendor ID, product code, CANopen protocol revision, and controller serial number.
- 5500_h – NVM (EEPROM) format.
- 5501_h – Internal ROM checksum.

Battery monitoring

The controller measures actual battery voltage at two points:

- Battery voltage; measured at keyswitch input and read at 5100_h sub-index 1.
- Capacitor voltage; measured at the B+ terminal and read at 5100_h sub-index 2.

The controller also has a battery discharge indicator (BDI), which can be read at 2790_h.

Hours counters

The controller supports many different hours counters for various functions. Some counters run on all units and some only run on the Gen4 size 8 configured as the vehicle master.

Hours counters are preserved with a minimum resolution of 15 seconds when the system is powered down.

Local hours counters

Local hours counters which run on all units are:

- Controller key hours: increments while the keyswitch is in the ON position (5200_h).
- Controller pulsing hours: increments when the controller is powering its connected motor (4601_h).

Vehicle hours counters

Vehicle hours counters which run only on the Gen4 size 8 configured as the vehicle master are:

- Vehicle key hours: increments as controller key hours (2781_h).
- Vehicle traction hours: increments when the vehicle is driving or braking (2782_h).
- Vehicle pump hours: increments when the pump motor is running (2783_h).
- Vehicle power steer hours: increments when the power steer motor is running (2784_h).
- Vehicle work hours: increments when the traction, pump or power steer motors are running (2785_h).

Since these hours are specific to the vehicle, they are writeable so that they can be reset to known good values if the master controller is replaced.

Logging

The controller can log events in the system (along with additional event-related information) and minimum and maximum levels of important parameters. You need different levels of access to clear the contents of the logs.

Logs are normally reset individually. However, to reset all logs at once write to 4000_h.

FIFO event logs

Events are recorded by these two separate FIFOs (first in, first out logs), which operate identically:

- System: this FIFO is 20 elements deep and is used for events such as software upgrades, user logins and some hardware upgrades (4100_h to 4102_h).
- Faults: this FIFO is 40 elements deep and is used for fault logging (4110_h to 4112_h).

At object $41X0_h$:

- Reset the FIFO
- Read its length

You can access the FIFO using objects $41X1_h$ and $41X2_h$. The FIFO index is entered at $41X1_h$ and the data is read from $41X2_h$.

Event counters

The controller provides 10 event counters at 4200_h to $420A_h$. Each event counter can record information about occurrences of one event. The allocation of event counters to events is user-configurable however Gen4 size 8 will automatically count important events in unused counters. The information recorded in each event counter is:

- The time of the first occurrence
- The time of the most recent occurrence
- The number of occurrences

Operational monitoring

At objects 4300_h and 4301_h, Gen4 size 8 monitors and records the minimum and maximum values of these quantities:

- Battery voltage
- Capacitor voltage
- Motor current
- Motor speed
- Controller temperature

Two instances of the operational monitoring log are maintained. Service engineers can access and clear the first log; the second is accessible and clearable only by Sevcon engineers. The Customer copy is normally recorded and reset each time the vehicle is serviced. The Sevcon copy records data over the controller's entire working life.

CANopen abort code

The controller will sometimes respond with a CANopen General Abort Error (08000000_h) when the object dictionary is accessed. This can occur for many reasons. Object 5310_h gives the exact abort reason. These are:

0	None	12	Invalid value	24	Cannot read from DSP
1	General	13	EEPROM write failed	25	Peek time out
2	Nothing to transmit	14	Unable to reset service time	26	Reserved for future use
3	Invalid service	15	Cannot reset log	27	Reserved for future use
4	Not in pre-operational	16	Cannot read log	28	Reserved for future use
5	Not in operational	17	Invalid store command	29	Reserved for future use
6	Cannot go to pre-operational	18	Bootloader failure	30	Reserved for future use
7	Cannot go to operational	19	DSP update failed	31	Reserved for future use
8	Access level too low	20	GIO module error failed	32	Checksum calculation failed

9	Login failed	21	Backdoor write failed	33	PDO not copied
10	Range underflow	22	Reserved for future use		
11	Range overflow	23	Cannot write to DSP		

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Faults and warnings

Introduction

In the event of a fault Gen4 size 8 takes the following action:

1. Protects the operator and vehicle where possible (e.g. inhibits drive).
2. Sends out an EMCY message on the CANbus.
3. Flashes the LED in a pattern determined by the fault type and severity.
4. Logs the fault for later retrieval.

Fault identification

You can identify a fault as follows:

- Check the number of LED flashes and use below to determine what action can be taken. A complete and comprehensive fault identification table will be available from Sevcon in due course.
- Pick up the EMCY on the CANbus and read the fault condition using configuration software
- Interrogate the fault on the node directly using DVT or other configuration software.

LED flashes

Use below to determine the type of fault from the number of LED flashes. The LED flashes a preset number of times in repetitive sequence (e.g. 3 flashes – off – 3 flashes – off – and so on). Only the faulty node in a multi-node system flashes its LED. Possible operator action is listed in the right hand column of the table.

LED flashes	Fault	Level	Set conditions	Operator action
0 (off)	Internal hardware failure	RTB	Hardware circuitry not operating.	
1	Configuration item out of range	VS	At least one configuration items is outside its allowable range.	Set configuration item to be in range. Use 5621_h to identify out of range object.
1	Corrupt configuration data	VS	Configuration data has been corrupted.	
1	Hardware incompatible with software or invalid calibration data	VS	Software version is incompatible with hardware. Calibration data for sensors invalid.	
2	Handbrake fault	I	Direction selected with handbrake switch active.	Release handbrake
2	Sequence fault	DI	Any drive switch active at power up.	Reset drive switches
2	SRO fault	DI	FS1 active for user configurable delay without a direction selected.	Deselect FS1 and select drive
2	FS1 recycle	DI	FS1 active after a direction change	Reset FS1

LED flashes	Fault	Level	Set conditions	Operator action
2	Seat fault	DI	Valid direction selected with operator not seated or operator is not seated for a user configurable time in drive.	Must be seated with switches inactive
2	Belly fault	DI	Set after belly function has activated.	
2	Inch sequence fault	DI	Inch switch active along with any drive switch active (excluding inch switches), seat switch indicating operator present or handbrake switch active.	
2	Invalid inch switches	DI	Inch forward and inch reverse switches active simultaneously.	Both inch switches inactive.
2	Two direction fault	DI	Both the forward and reverse switches have been active simultaneously for greater than 200 ms.	Reset switches
2	Invalid steer switch states	VS	Steering switches are in an invalid state, for example, both outer switches are active.	Check steer switches.
3	Fault in electronic power switching circuit	VS	Fault in electronic power switching circuit (e.g. MOSFET s/c).	
3	Hardware over voltage activated	VS	Hardware over voltage circuit activated	Investigate and reduce battery voltage below user defined maximum level. Ensure suitable over voltage is configured in $2C01_h$ and 4612_h.
3	Hardware over current trip activated	VS	Hardware over current circuit activated	Check motor load and wiring. Check motor parameters are correct.
4	Line contactor welded	S	Line contactor closed at power up or after coil is de-energized.	Check line contactor condition/wiring.
4	Line contactor did not close	S	Line contactor did not close when coil is energized.	Check line contactor condition/wiring.
5	PST fault	DI	Fault detected on PST power steer module.	Check PST condition.
5	Motor open circuit	S	Unable to establish current in motor.	Check motor condition/wiring.
5	Pulsed Enable Signal	W	Set to indicate pulsed enable signal is not detected	Check pulsed enable signal wiring, check pulse is present.

LED flashes	Fault	Level	Set conditions	Operator action
6	Throttle pressed at power up	DI	Throttle demand is greater than 20% at power up.	Reduce demand
6	Analog input wire-off	VS	Analog input voltage is outside allowable range.	Check analog input wiring
6	Analog output fault (over/under current, failsafe, short circuit driver)	VS	Analog output fault caused by over current (>4A), under current if actual current < 50% target (current mode only), failsafe circuit fault, short circuit driver MOSFET.	Check analog output wiring.
7	BDI warning or cut-out	I	BDI remaining charge is less than warning or cut-out levels.	Charge battery.
7	Battery low voltage protection	I	Battery voltage or capacitor voltage is below a user definable minimum battery level for a user definable time.	Increase battery voltage above user defined level
7	Controller low voltage protection	I	Battery voltage or capacitor voltage is below the minimum level allowed for the controller.	Increase battery voltage above minimum level
7	Controller high voltage protection with line contactor closed.	I	Battery voltage or capacitor voltage is above the maximum level allowed for the controller with line contactor closed.	Investigate and reduce battery voltage below maximum level.
7	Battery high voltage protection	I	Battery voltage or capacitor voltage is above a user definable maximum battery level for a user definable time.	Investigate and reduce battery voltage below user defined maximum level.
7	Motor low voltage protection	I	Capacitor voltage has entered the motor low voltage cutback region defined in 4612_h.	Increase battery voltage above start of motor low voltage cutback region.
7	Motor high voltage protection	I	Capacitor voltage has entered the motor high voltage cutback region defined in 4612_h.	Reduce battery voltage below start of motor high voltage cutback region.
7	Controller high voltage protection with line contactor open.	S	Battery voltage or capacitor voltage is above the maximum level allowed for the controller with line contactor open.	Isolate controller and investigate high battery voltage
7	Battery voltage below critical level for controller.	S	Battery voltage is below the absolute minimum voltage at which the controller hardware is guaranteed to operate.	Increase battery voltage.

LED flashes	Fault	Level	Set conditions	Operator action
7	Precharge failure	VS	Capacitor voltage is less than 5V after pre-charge operation is complete.	Check controller wiring to ensure there are no short circuits between B+ and B-.
8	Controller too hot	I	Controller has reduced power to motor(s) below maximum specified by user settings due to controller over temperature.	Remove loading to allow controller to cool down.
8	Controller too cold	I	Controller has reduced power to motor(s) below maximum specified by user settings due to controller under temperature.	Allow controller to warm up to normal operating temperature.
8	Motor over temperature	I	Controller has reduced power to motor(s) below maximum specified by user settings due to motor over temperature.	Reduce load to motor to allow it to cool down.
8	Motor too cold	I	Motor thermistor reports less than -30°C.	Allow motor to warm up. Check motor thermistor.
8	Heatsink over temperature	VS	Heatsink temperature measurement has exceed absolute maximum for controller and system has powered down.	Remove loading to allow controller to cool down.
10	Pre-Operational	I	Controller is in pre-operational state.	Use DVT to put controller into operational state.
10	I/O initializing	I	Controller has not received all configured RPDOs within 5s of power up.	Check CANbus wiring and PDO configuration.
10	RPDO Timeout	I / DI / S	One or more RPDOs have not been received within 3s at power up or within 500ms during operation.	Check CANbus wiring and PDO configuration.
11	Encoder fault	VS	Speed measurement input wire-off is detected.	Check encoder wiring
11	Over current	VS	Software has detected an over current condition	Check motor load and wiring. Check motor parameters are correct.
11	Current Control fault	VS	Software is unable to control currents on PMAC motor.	Check motor load and wiring. Check motor parameters are correct.
12	Communication error	S	Unrecoverable network communication error has been detected.	Check CANbus wiring and CANopen configuration.
13	Internal software fault	RTB	Software run time error captured	

LED flashes	Fault	Level	Set conditions	Operator action
13	Current sensor auto-zero fault	RTB	Current sensor voltage out of range with no current.	
13	DSP parameter error	RTB	Motor parameter written to while motor control is operational.	Recycle keyswitch to allow parameters to be reloaded correctly.
14	3rd Party Anonymous Node EMCY received	I / DS / RTB	3rd party node has transmitted an EMCY message.	Check CANbus wiring and 3rd party node status.
15	Vehicle service required	I	Vehicle service interval has expired.	Service vehicle and reset service hours.

Table 7 Fault identification

Fault list

Use DVT to access the Fault list. If you don't have DVT you can use any configuration tool as follows:

1. Object 5300_h gives information about all active faults. Read sub-index 1 to get the number of active faults. Write to sub-index 2 to select one of the active faults (0 = highest priority) and read back sub-index 3 to read the fault ID at that index.
3. Object 5610_h can be used to read a text description of the fault. Write the fault ID to sub-index 1 and read back the fault description from sub-index 2.

Upgrading the controller software

It is possible to field update the firmware of the Gen4 size 8 controller , typically using Sevcon's DVT configuration tool.

Please contact Sevcon for assistance with this process.