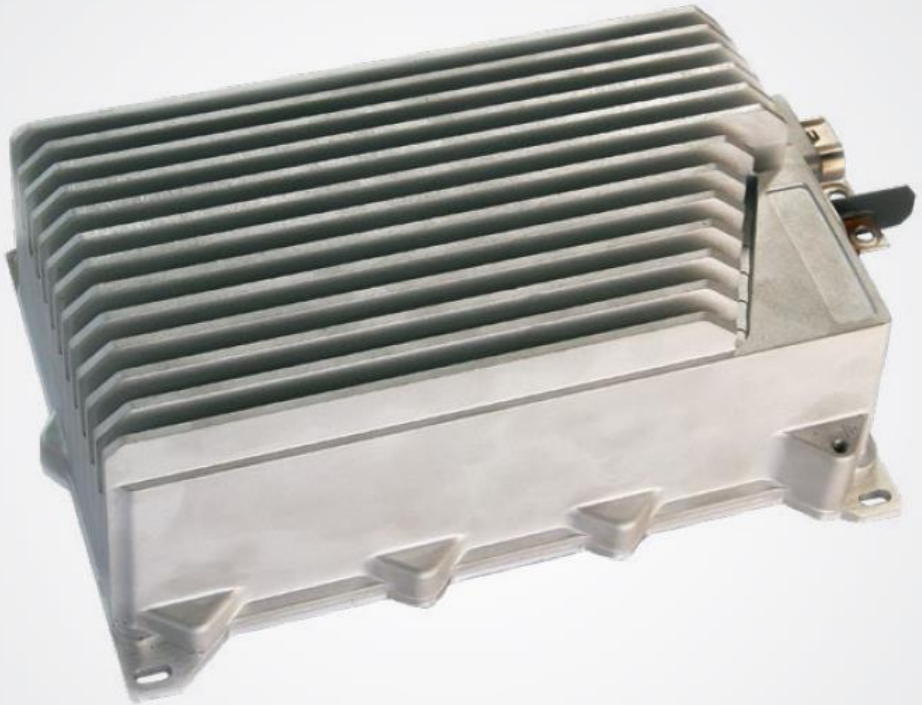

Hybrid Electric

Explore Our Technologies

Gen5 High Voltage DC/DC Converter

Reference Manual V1.6

www.borgwarner.com

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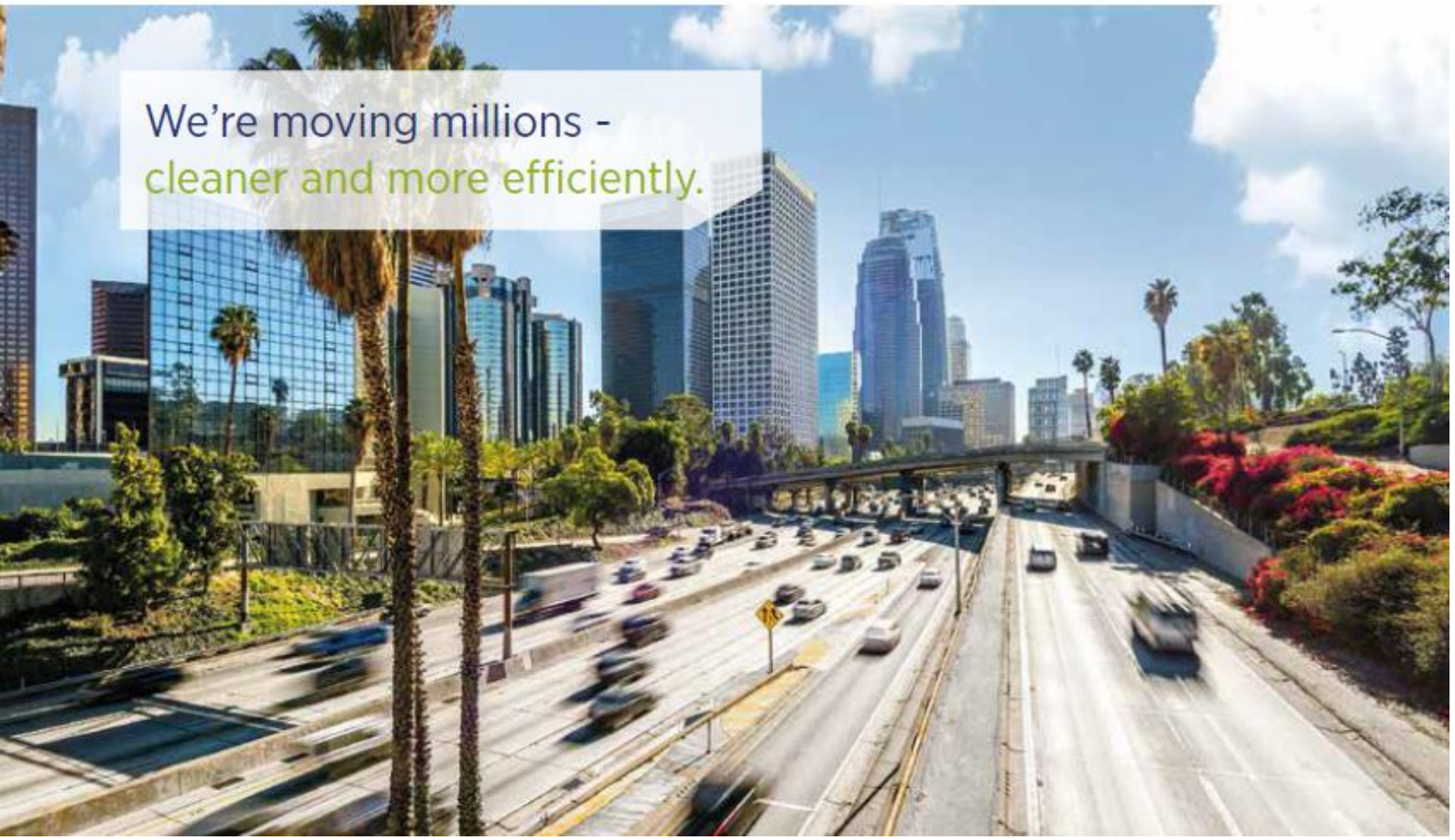
Hybrid
Electric


We're moving millions -
cleaner and more efficiently.

BorgWarner

Chapter 1: Legal Disclaimer

Chapter 1 - Legal Disclaimer

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Chapter 2: Introduction

Reliably delivering what's needed today

There are few challenges as important today as creating solutions that support a cleaner, more energy-efficient world. This requires a commitment to constantly improve the transportation of people and things. We, at BorgWarner, made that commitment decades ago and have since been creating technologies to improve efficiency, emissions and performance in all types of vehicles.

Constantly pursuing what's next

Our proven track record has made us propulsion system leader for combustion, hybrid and electric vehicles. We uncover strong trends and use smart science and technology to address a future based on varying regulations, consumer demands and automaker requirements.

Product leadership that's changing the world

Our employees have earned trusted partnerships with customers and suppliers around the world. We leverage these relationships to gain a deeper understanding of the challenges at hand and then do what it takes to develop the next solution. Our strong operations and commercialization expertise result in high volume availability of competitive, efficient products that truly drive change.

BorgWarner enables the switch - To highly efficient electric drives

Chapter 2 - Introduction

2.1 About BorgWarner's Technologies

Transforming vehicles to more fuel efficient, cleaner technologies requires a collaborative partner who understands the evolution of mechanical to electric systems. Our expertise in both provides the critical underpinnings of efficient and powerful propulsion. Integrating electronics into the mechanical system is the key to performance, packaging and cost. This is evidenced across a full line of our combustion, hybrid and EV products for light vehicles, medium & heavy-duty vehicles as well as off-highway applications.

2.1.1 Sevcon

BorgWarner announced on 28th September 2017 that it has finalized its acquisition of Sevcon, Inc. A global player in electrification technologies, Sevcon complements BorgWarner's power electronics capabilities utilized to provide electrified propulsion solutions.
https://www.borgwarner.com/acquires/sevcon

SEVCON®
Electrification Partner

2.2 Purpose of this Manual

To support decision-makers, the first four chapters of this manual are intended to provide an overview of the HV DC/DC Converter product, and where this product could be applied.

The installation instructions in this manual, which have been written for qualified electrical and mechanical installation engineers, presents the basics of installing the HV DC/DC Converter. Guidance is provided to support engineers when configuring converter systems, and selecting system components, options and accessories. The installation instructions are housed in chapters five to eight.

Please pay special attention to the information relating to warnings, cautions and notes when they appear in the manual.

2.2.1 The version of the manual

This version of the HV DC/DC Converter manual replaces all previous versions. BorgWarner 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.

2.2.2 Scope of this manual

The manual provides important information on configuring the DC/DC converter, installation instructions and specification. This version of the manual applies to all HV DC/DC converter with BorgWarner part numbers:

622/11143 – Gen5 HV DC/DC 12V to 13.5V output (1200W)
622/11144 – Gen5 HV DC/DC 12V to 14.5V output (1200W)

2.2.3 Related documents

The following documents are available from BorgWarner and Authorized Distributors:

- DVT software user manual
- The Object Dictionary providing important information about CANopen communication and configuration

2.3 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 BorgWarner always have your product's Type number, Part number and Serial number available.

2.4 Sales and Technical support

BorgWarner is a major OEM focused business; however, we have an extensive authorized distributor network who can provide you with technical or commercial support. Please find the details of your nearest distributor through the following link https://www.borgwarner.com/aftermarket/controllers-converters/distributor-search

For direct customers of BorgWarner please contact one of the following BorgWarner offices for assistance:

- North America Office:
  - BorgWarner Southborough Inc. (US.drives.sales@borgwarner.com)
- European Office (+ Rest of World):
  - BorgWarner Systems Lugo S.r.l. (drives.sales@borgwarner.com)

2.5 Document Conventions

The following conventions are used within this document. 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:

Convention	Description

	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 BorgWarner product.
Illustrations	Orthographic illustrations are drawn in third angle projection.
Units	SI units are used throughout.
Bold text	Used in procedures for names of interface elements, such as names of buttons, fields, and tabs. Also used to introduce a procedure.

Table 1 Manual Conventions

2.6 Our Controllers and Converters

BorgWarner controllers are designed to control the following motors, in battery and generator-powered applications:

- 3-phase AC induction motors
- 3-phase permanent magnet AC (PMAC) motors, both surface and interior magnet

BorgWarner also has a range of DC/DC converters:

- Gen5 HV isolated DC/DC
- Low voltage isolated DC/DC

Gen5 HV DC/DC

Wide input voltage 220V – 800V

Maximum output power 1200W with air cooled variant

Nominal output voltage options:

- 12V to 14.5V 1.2KW
- 24V 50A (contact BorgWarner for more information)

Controlled via digital input or over CAN bus

Configuration and control of BorgWarner Converters are fully customizable.

However, for a bespoke solution, please contact us for further information.

Chapter 3: About the Gen5 HV DC/DC

Chapter 3 - About the Gen5 HV DC/DC

3.1 Overview of Specification

The isolated DC/DC converter from BorgWarner is an air cooled 1200W DC/DC converter intended for use in hybrid and electric vehicles for powering low voltage accessories, this is achieved by utilizing a high efficiency topology. The very wide input voltage range allows the converter to be used over many different applications.

The DC/DC converter is designed to operate over a temperature range of -40˚C to +80˚C and has many protection features such as input under/over voltage lockout, output overcurrent protection and over temperature protection. Parallel connection of multiple units with forced current sharing is also possible (contact BorgWarner for more information).

A CAN bus is available for programming of output voltage set-point and reporting of converter parameters. Also included is DC/DC enable input pin and remote power on output signal for use when no CAN communication is available.

3.2 Principles of operation

3.2.1 Functional description

The main function of the Gen5 HV DC/DC is intended to convert the vehicle high voltage battery supply into a 12V to 14.5V (adjustable) output voltage to power the low voltage vehicle system.

3.2.2 Internal subsystems

The electrical circuit blocks present in the HV DC/DC have the following functions:

- Isolated voltage conversion – This converts the HV battery supply into a low voltage supply through an isolating transformer
- Control logic – software runs on microprocessor circuits with input and output circuits for control and status I/O

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

Note: All the control inputs and outputs, such as the enable digital input are referenced to the 12V logic circuit ground. The CANbus is also referenced to the 12V logic circuit ground.

3.2.3 Interfaces

A digital “enable” input and “power OK” digital output are supported.

HV DC/DC connectivity and interoperability with other system devices (for example A VCU) using a CANbus through CANopen protocol is provided. In addition to in-service operation, the CANopen protocol allows the controller to be commissioned using the BorgWarner DVT tool.

3.2.4 General operation

The HV DC/DC functions as shown in the figure below.

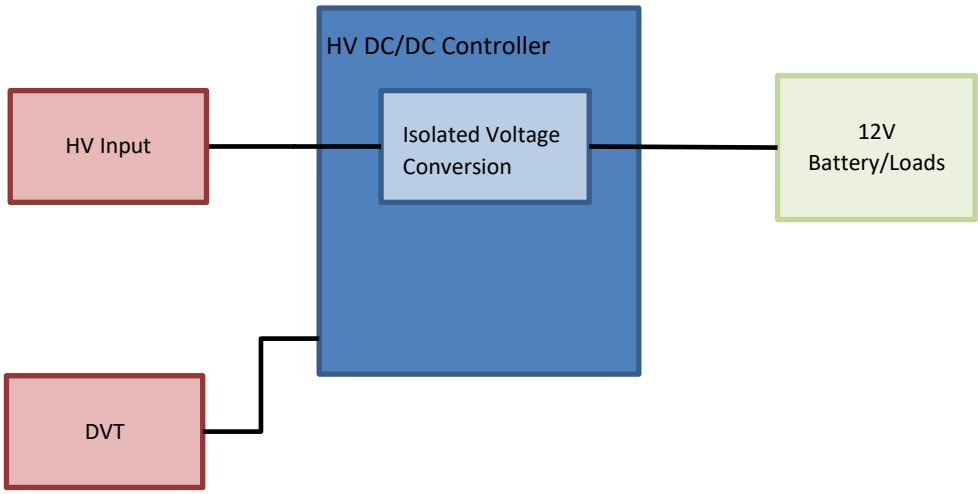

Figure 1 HV DC/DC converter functions

3.3 Safety and protective functions

3.3.1 General

WARNING Electric vehicles can be dangerous. All testing, fault-finding and adjustment should be carried out by competent personnel. The vehicle manufacturer's manual should be consulted before any operation is attempted.

WARNING The battery or generator must be disconnected before replacing the converter. 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.

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. Controller discharge time shown on page 17.

WARNING Never connect the converter to a battery with vent caps removed or a generator with an open fuel tank as an arc may occur due to the converter internal capacitance when first connected.

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

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

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 HV DC/DC Converter should be carefully considered and relevant safety precautions taken. The HV DC/DC Converter has several features which can be configured to help the system integrator to meet vehicle safety standards. BorgWarner accepts no responsibility for incorrect application of their products.

3.4 Product warranty

Please refer to the terms and conditions of sale or contract under which the HV DC/DC Converter was purchased for full details of the applicable warranty

Chapter 4: Specification

Chapter 4 - Specification

4.1 Electrical Characteristics

4.1.1 Input characteristics

All electrical specifications are based on 25˚C ambient temperature unless otherwise stated.

Input characteristics	Min	Typ	Max	Units	Notes
Input voltage range	220	500	800	V_{dc}	
Input UVLO, turn-on	210	215	220	V_{dc}	
Input UVLO, turn-off	205	210	215	V_{dc}	
Turn-On delay			2	seconds	Vin = 220V Vout = 90% of Vnom
Max input current			6.1	A_{dc}	Vin = 220V Pout = 1.2KW
Max off-state input current			5	mA_{dc}	Vin = 500V Output disabled
Input capacitance		6		µF	

Table 2 Input characteristics

Internal capacitor discharge time.

Before handling the controller or working near exposed terminals, allow a minimum of 5 seconds for internal capacitors to discharge after the high voltage connection is removed from the input.

4.1.2 Output characteristics

Output characteristics	Min	Typ	Max	Units	Notes
Output power			1200	W	
Output current range	0		83-100	A_{dc}	Depends on output V set point.
Output voltage set point	11.0	13.4	14.5	V_{dc}	Programmable via CAN
Output voltage regulation		+/-3		%	From Vout set point 0% to 100% load
Output ripple and noise			250	mV	20MHz BW, 100% load. 47µF electrolytic and 1µF ceramic capacitors at measuring point
Output voltage transient regulation		+/-5		%	From Vout set point, Vin typ,10A-50A dynamic, 0.1A/µs
Output overshoot			3	%	
Current share accuracy			5	%	20% - 100% load Max of 6 units in parallel.
Over voltage protection	16			V_{dc}	Auto restart
Over current protection	110			A_{dc}	Auto restart once the fault is removed
Output quiescent current			100	µA	Converter shut down with 12V applied to output
Efficiency (Vout = 13.4)	92			%	50% load, Vin Typ
	92			%	75% load, Vin Typ
	92			%	100% load, Vin Typ

Table 3 Output characteristics

Note 1: Configurable output voltage set-point is currently restricted to 14.5V

4.1.3 Regulatory compliance

Regulatory	Description	Criteria
Isolation	Reinforced: 4.25kV dc	Input to Output
Isolation	Basic: 3.2kV dc	Input to Chassis
EMC Emissions	UN ECE R10 4th Edition	ESA level
EMC Immunity	UN ECE R10 4th Edition	ESA level, TEM cell method at 75V/m
BCI	UN ECE R10 4th Edition	ESA level, 60mArms
ESD	EN 61000-4-2	+/-6kV contact, +/-8kV air. Performance criteria B

Table 4 Regulatory compliance

4.1.4 Electrical measurements

4.1.4.1 Efficiency

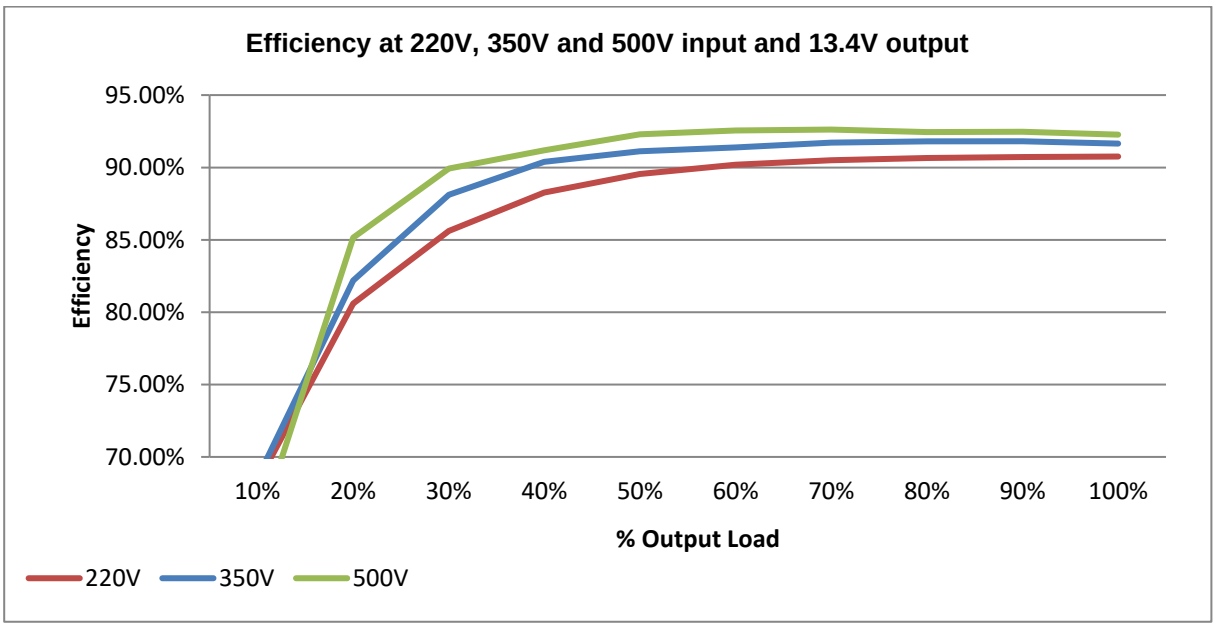

Figure 2 Efficiency at varying input voltage and load

4.1.4.2 Output ripple and noise

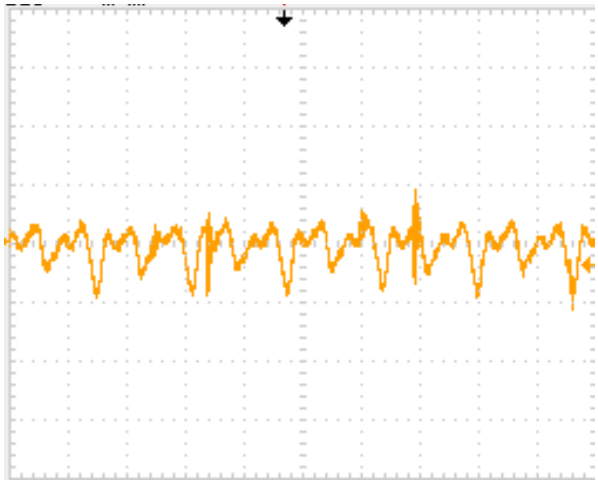

Figure 3 Output ripple and noise

Vin=220V, Iout Max, 20MHz BW

CH1: Vout, 50mV/div 5us/div

4.1.4.3 Start-up waveform

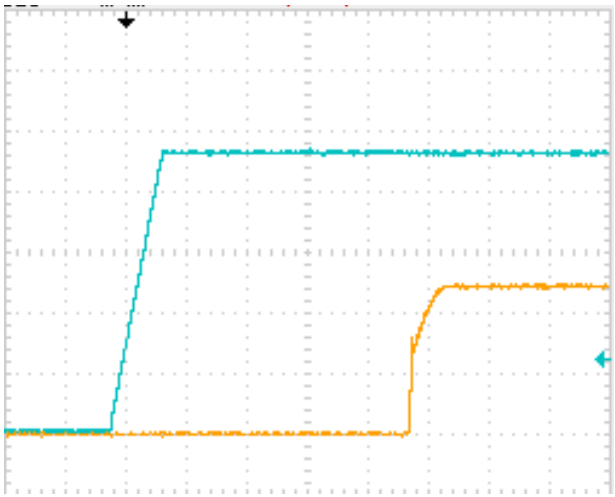

Figure 4 Start-up waveform

Vin=220V, Iout Max

CH1: Vin, 50V/div 200ms/div

CH2: Vout, 2V/div 200ms/div

4.1.4.4 Control Loop Dynamic response

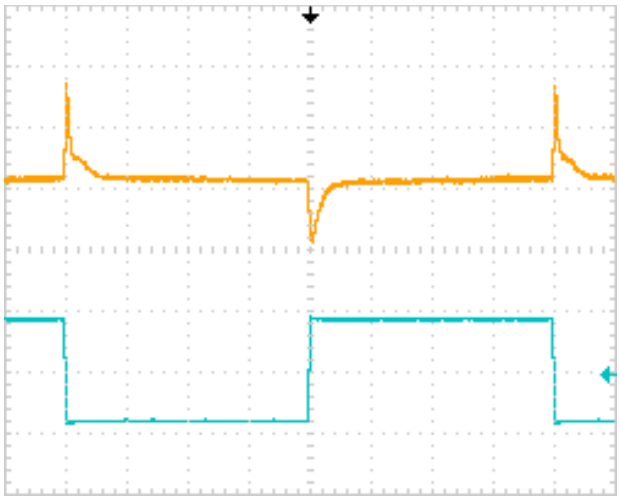

Figure 5 Control Loop Dynamic response

Vin=220V, Iout= 10-50A 0.1A/us

CH1: Vout, 200mV/div, 5ms/div

CH2: Iout, 25A/div 5ms/div

4.2 Mechanical Characteristics

Environmental	Min	Typ	Max	Units
Storage temperature	-40		+80	˚C
Operating temperature	-40		+80	˚C
Humidity (condensing)	0		95	%RH
Ingress Protection	IP6X (contact BorgWarner)			
Vibration	5G rms,0-500Hz, 3 planes			
Shock	50Gpk, 3 planes			
Weight (Air cooled)	4.4 Kg			

Table 5 Environmental characteristics

4.2.1 Cooling and output rating

The curve below shows the continuous output limit the controller is designed to operate within at a given ambient temperature. The controller doesn't limit output by ambient temperature, so it is possible to draw maximum power output above 45C for a short period of time. However if the limit is exceeded for long enough the controller will set a non-recoverable fault and shut down to protect itself.

The application should be designed to stay within the operating curve below to prevent setting of the overtemp fault.

Cooling	Max power at 45 °C ambient, with 1m/s airflow Application should limit output power above 45 °C to match this curve.

Table 6 Cooling requirements

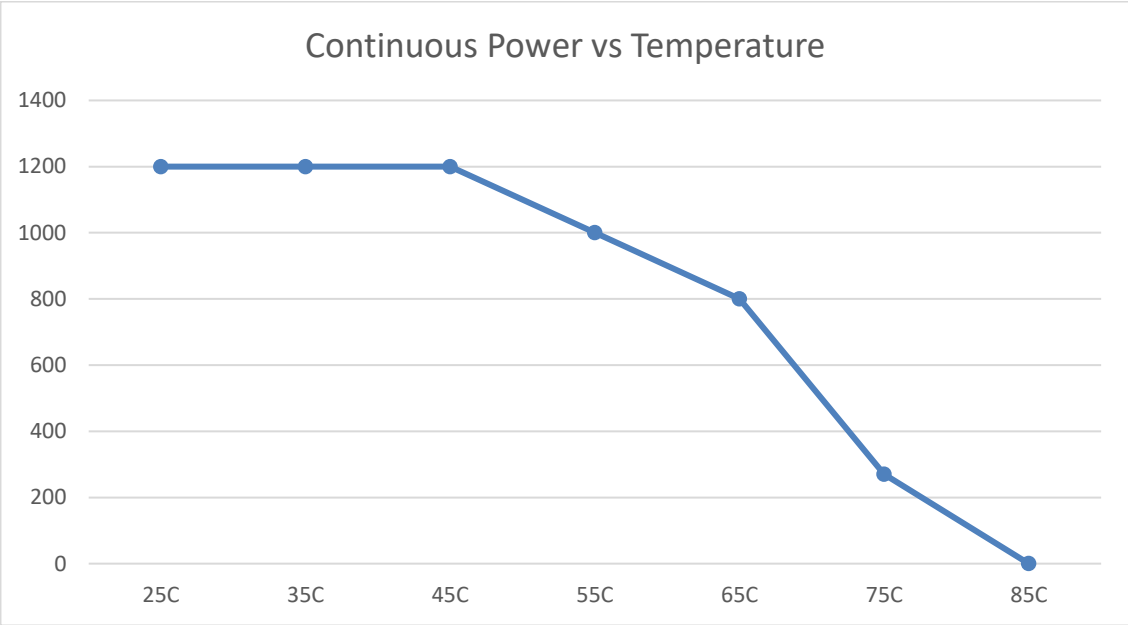

Figure 6 Maximum output by ambient temperature for air cooled variant

4.2.2 Mechanical Drawings

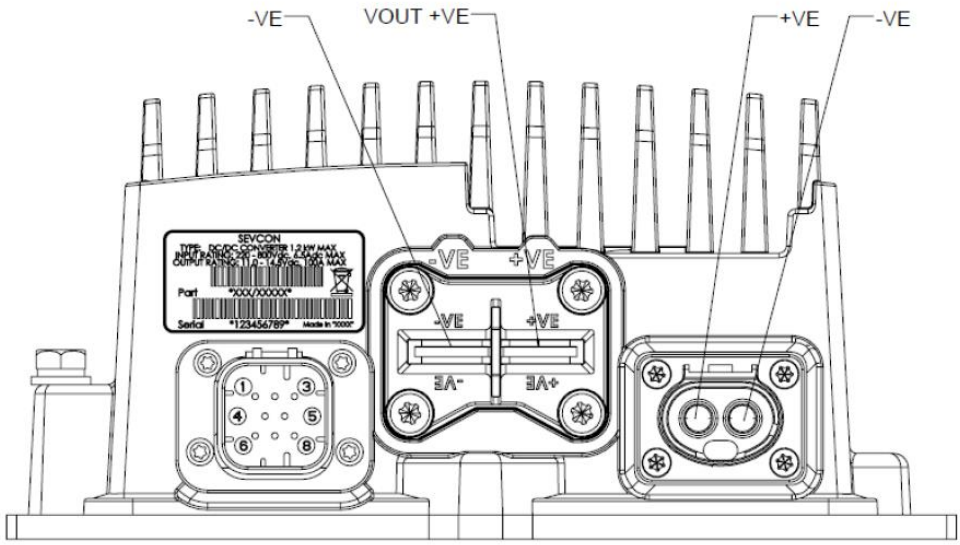

Figure 7 Gen5 HV DC/DC connectors

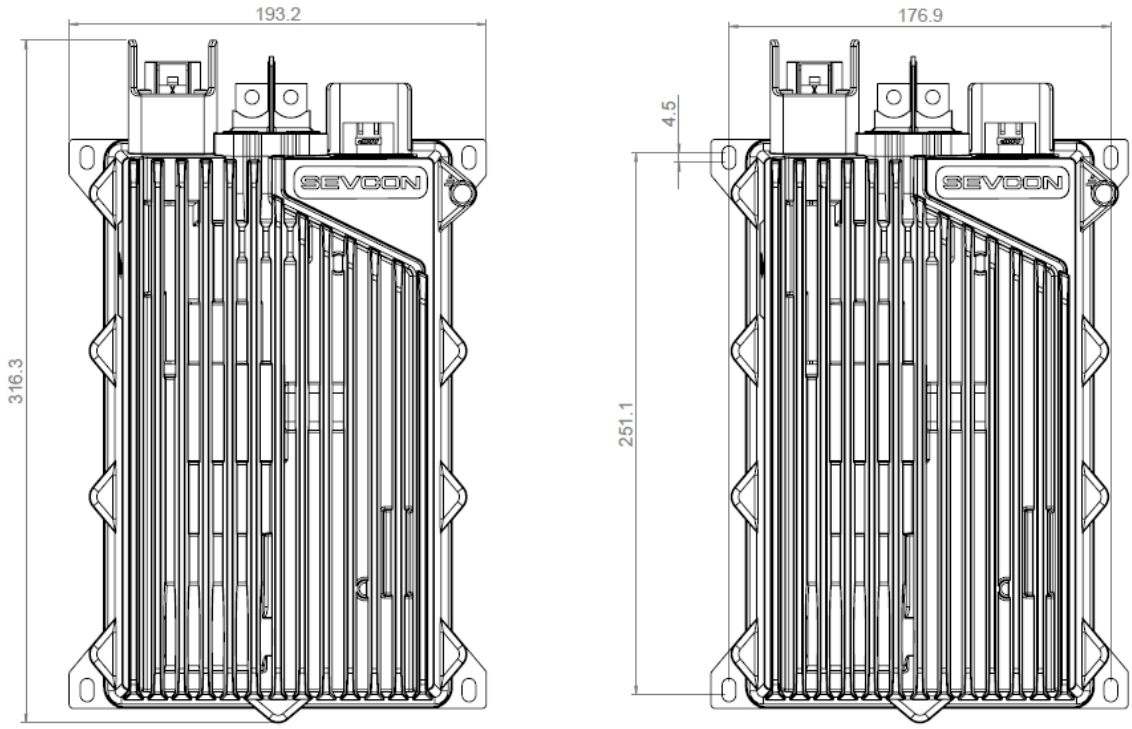

Figure 8 Gen5 HV DC/DC from above

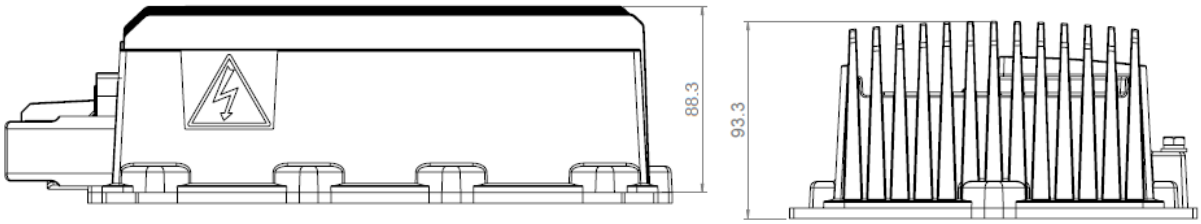

Figure 9 Gen5 HV DC/DC from side

Chapter 5: Installation

Chapter 5 - Installation

5.1 Mounting Gen5 HV DC/DC

5.1.1 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 accessible to unauthorized personnel.
- Do not mount the controller where it may be susceptible to damage due to minor collisions or impact from road debris.
- Do not mount the controller in the passenger compartment or in the luggage compartment of a road vehicle (See UNECE-REG. 100 clause 5.1.1.3)
- Do not mount the controller in the operator station area of a tractor (see ISO16230-1 2013, clause 5.3
- 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.
- Take note of the thermal and EMC considerations as explained later in this section of the manual.

5.1.2 Orientation

The controller must be located with the heatsink fins running vertically and in a location with greater than 1m/sec air flow and the ambient temperature does not exceed 45º Celsius (reduced power for temperatures above between 45 and 80º Celsius).

It is strongly recommended that the unit baseplate should be mounted to a metal panel which should be substantial enough to provide some additional conductive cooling. A fan is recommended to provide a 1m/s airflow across heatsink fins.

5.1.3 Mounting hole pattern

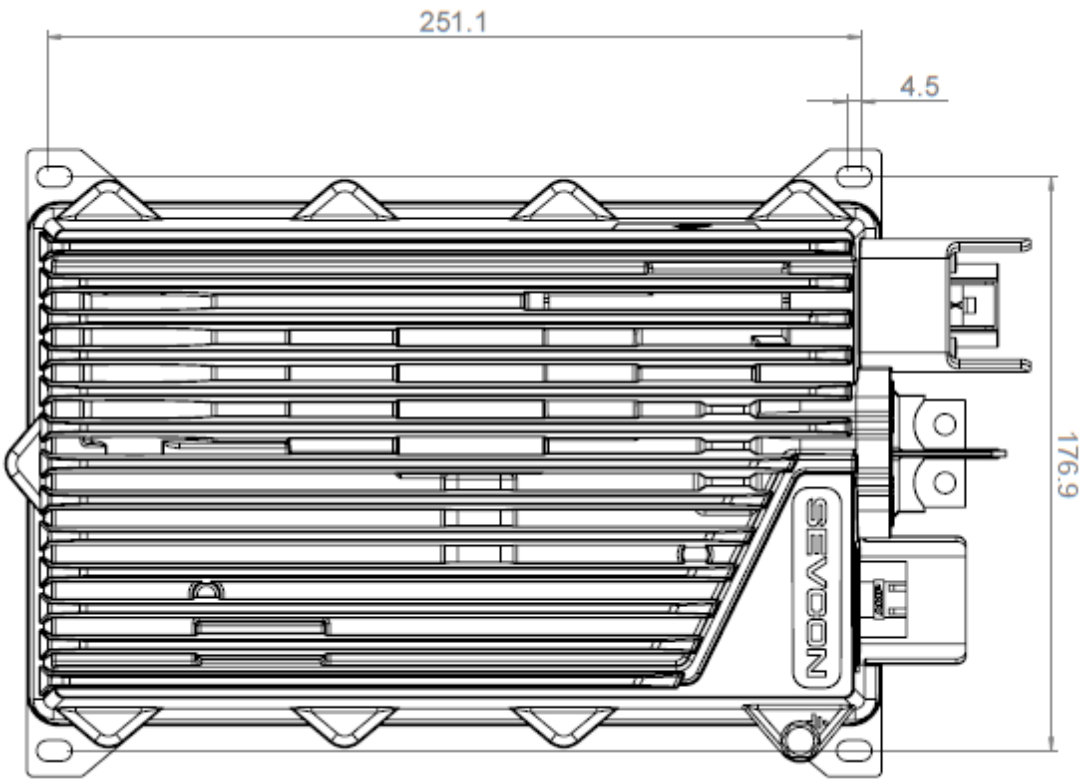

Figure 10 Gen5 HV DC/DC Mounting Hole Pattern

(Note: above dimensions expected to be within +/-1.0mm)

The DC/DC 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.

5.1.4 Equipment required

- 4 x M6 socket cap head bolts (minimum strength 4.8), nuts and spring washers. Bolts need to be long enough to pass through 5mm of the DCDC base plate and your mounting surface thickness.
- T hand-socket wrench or Allen key

Recommended torque setting: 10 Nm ± 2 Nm

5.2 Logic IO connector

The logic IO connector requires an 8-way AMPSeal connector TE Connectivity P/N 776286-1. The following terminals are recommended for wire sizes 0.5mm^2 to 1.25mm^2, TE Connectivity P/N 770854-1.

Pin #	Name	Description
1	PSON	Active low input
2	PSOK	Active high output
3	CAN_TERM	Connect to CAN_L to use internal 120 Ohm termination resistor
4	VOUT_NEGATIVE	Signal negative
5	CAN_H	CANbus high signal
6	CS	Current share signal. Connect to other units CS signal for parallel operation
7	CAN_GND	Isolated GND for CAN
8	CAN_L	CANbus low signal

Table 7 Logic I/O connector pinout

Gently push the connector housing onto the mating half of the Gen5 HV DC/DC. Never force a connector. Mating ends are keyed to prevent incorrect insertion.

Inserting contacts into connector housing pierces the sealing diaphragm and forms a seal around the wire. If a contact is inserted and subsequently removed, it must be re-sealed with appropriate hardware (available from Tyco 770678-1) to maintain IP rating.

NOTE: Please see Tyco Application Specification 114-16016 and Instruction sheet 408-3229 before assembling the AMPSeal connector

Chapter 6: System Design

Chapter 6 - System Design

6.1 Initial power up sequence

6.1.1 Inrush current

Inrush current is controlled by external means; please refer to electrical specification for input capacitance.

6.2 Application Information

6.2.1 PSON input

The DC/DC converter has an enable input which can be used when no CAN bus communication is available. To enable the converter the Enable input should be shorted to Vout negative by an external relay or other means.

6.2.2 PSOK output

The DC/DC converter has a Power OK signal output. Once the converter is powered the Power OK signal will be pulled-up to 3.3V, in the event of any fault condition the Power OK signal will be pulled low. The Power OK signal is referenced to Vout negative.

6.2.3 CAN communication

CAN communication is used to enable the DC/DC, adjust Vout, adjust Iout Max, and for monitoring the DC/DC converter status. CANopen is the provided CAN protocol.

6.2.4 Output voltage set point

The output voltage set point is programmable via CAN between 11V to 14.5V. If CAN is not used the default set point is 14.5V at 50% load, other set points can be configured.

Note: Output voltage set-point is currently restricted to 14.5V maximum.

6.2.5 Parallel connection of multiple units

The DC/DC converter includes an active current share circuit for paralleling of multiple units. Each unit is connected to the next via the CS signal. Current sharing of units is used for increased system power or for when N+1 redundancy is required. Contact BorgWarner for more detail.

6.2.6 Reverse polarity protection

In the event that the output is wired incorrectly the DC/DC converter will self-protect. The input connector design ensures that the input cannot be reversed.

6.2.7 Overcurrent protection

In the event that the output is overloaded or shorted, the DC/DC converter will protect itself from excessive stress. The converter will continue to try and power-up, however, if the overload is still applied the output will shut down. Once the fault is removed the converter will power-up.

6.2.8 Thermal considerations

In the event excessive temperatures are reached, the DC/DC converter will set an overtemperature fault and shut down. This fault will reset once the converter cools.

6.2.9 Fusing

Input and output fusing are not provided within the Gen5 HV DC/DC. Suitable fuses should be installed in the end application.

WARNING It is the installer responsibility to ensure suitable fusing is installed to the input and output of the Gen5 HV DC/DC

6.2.10 Input connector

Input connector is Amphenol Power Lok part # PL082X-61-0.75

Mating connector is Amphenol Power Lok part # PL182X-61-2.5 or # PL182X-61-4.0

Note: Input connector HVIL pins are shorted together inside the converter

6.2.11 Output connector

Low voltage output connections are made via the output busbars.

Chapter 7: Configuration

Chapter 7 - Configuration

7.1 Introduction

Gen5 DC/DC is a High Voltage (HV) DC to DC converter with an input voltage operating range of 220 to 800V and can be configured to output a voltage from 11.0V to 14.5V.

There are two modes of operation:

- Local Control – A physical switch enables/disables output
- Remote Control – CAN messages enables/disables output

NOTE1: There is no internal pre-charge in the unit, therefore an external pre-charge is needed.

NOTE2: There is no input reverse polarity protection. Connecting the positive and negative inputs incorrectly WILL damage the unit beyond repair.

7.2 Configuration Parameters

The main parameters required to be configured (or mapped to an RPDO for CAN control) are stored in object 0x5C00.

Object Index	Sub Index	Scaling		Name	Data Type	Type
5C00h	1	1		PSON	Unsigned8	PDO mappable
	2	1		Use CAN PSON	Unsigned8	Parameter
	3	1.52588E-05	16.16	Vout (V)	Unsigned32	PDO mappable
	4	1.52588E-05	16.16	Imax (A)	Unsigned32	PDO mappable
	5	1.52588E-05	16.16	Vout default (V)	Unsigned32	Parameter
	6	1.52588E-05	16.16	Imax default (A)	Unsigned32	Parameter

Table 8 Configurable Parameters

NOTE: Prior to making configuration changes, you will have to login to the unit and set to pre-operational.

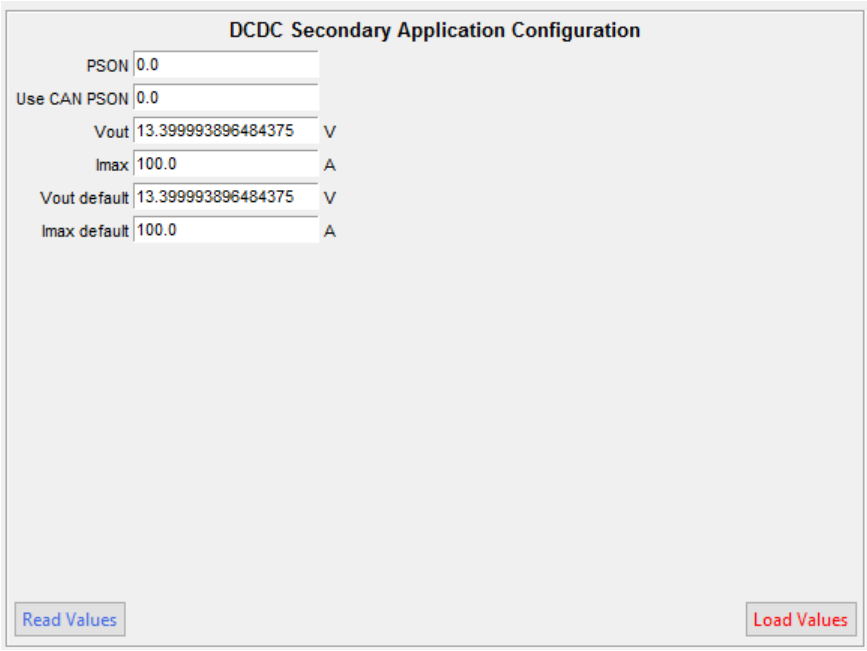

Figure 11 Object 0x5C00 in DVT Helper

Status can be monitored in object 0x5C01.

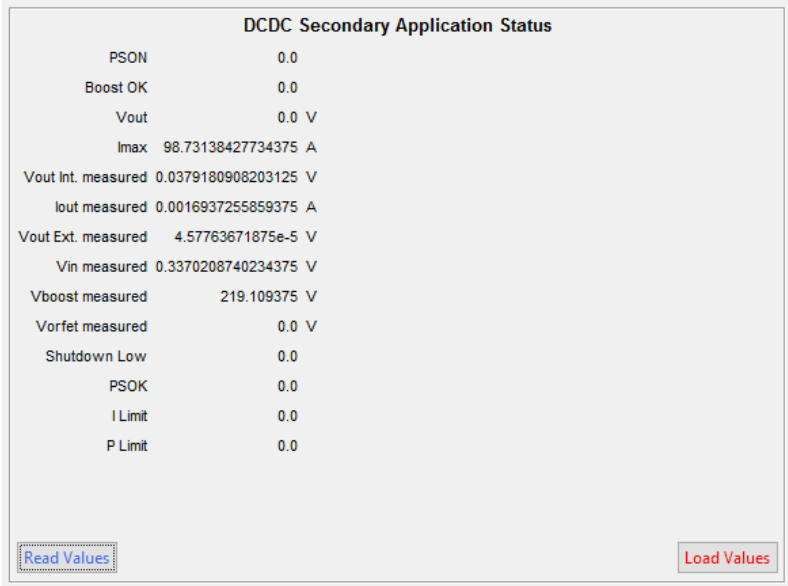

Figure 12 Example status when output is disabled

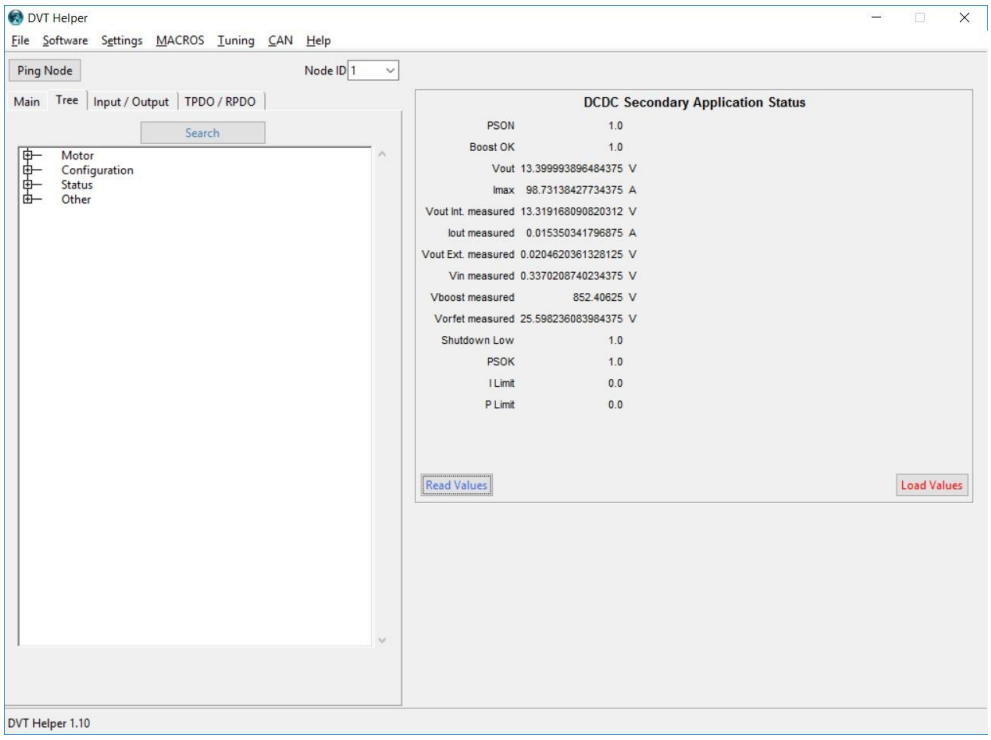

Figure 13 Example status when output is enabled.

Valid output can be seen by PSON and Boost OK being 1.0 whilst Vboost Measured is > 850V. Vout shows the output voltage, in this example, 13.39V

7.3 Local Control

Local control is the ability to enable and disable the output by changing the state of the PSON digital input using a physical switch.

Object Index	Sub Index	Name	Example Value	Description
5C00h	2	Use CAN PSON	0	Set to 0 for control via PSON digital input
5C00h	5	Vout default	12	Configured voltage set point
5C00h	6	Imax default	100	Configured maximum output current

Table 9 Local Control Setup Values

7.4 Remote Control

Remote control is the ability to enable and disable the output via the CAN.

7.4.1 Controller Side Configuration (Rx)

Object Index	Sub Index	Name	Value
5C00h	1	PSON	From RPDO
	2	Use CAN PSON	1
	3	Vout	12
	4	Imax	100
	5	Vout default**	From RPDO
	6	Imax default**	From RPDO

Table 10 Remote Control Setup Values

**These parameters are not used in Remote Control Mode

The RPDO's should be configured as seen here (however any required COB-ID can be used to support different CAN network requirements):

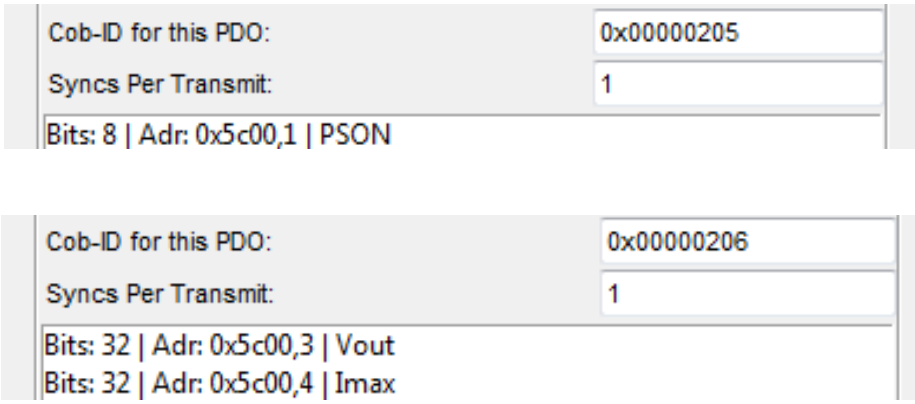

Figure 14 RPDO configuration in DVT

NOTE: In Local Mode, these RPDO's should be disabled i.e. 0x**8**0000205 and 0x**8**0000206

7.4.2 Master Node Configuration (Tx)

7.4.2.1 CANAlyzer

You can use the embedded CANAlyzer file to send messages to a Gen5 HV DC/DC unit. It is setup to request a 12V output and 100A maximum current.

You can do this by opening the IG window and ensuring that the box to transmit the messages is checked as shown in the screenshot below.

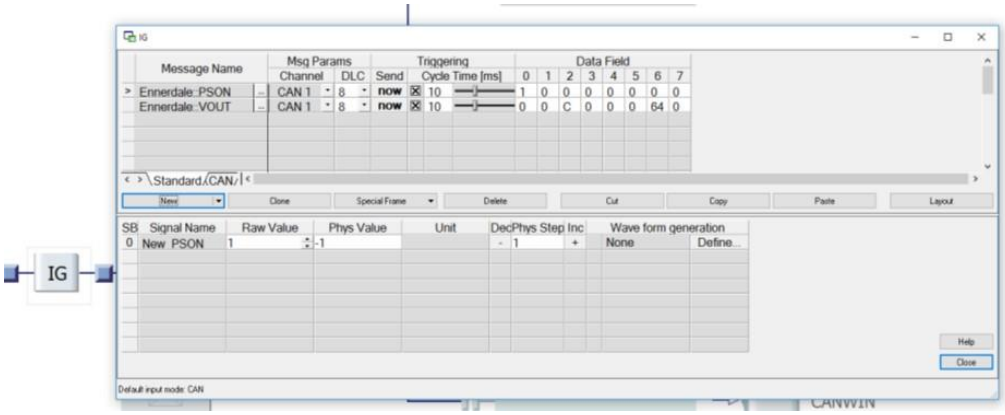

Figure 15 CANAlyzer window

7.4.2.2 Other CAN application or VCU

If using another CAN messaging application or configuring a VCU, you can configure the messages required to enable the output quite easily.

There should be two messages configured (however any required COB-ID can be used to support different CAN network requirements). See RPDO configuration on page 37.

Cob-ID: 0x00000205			
Byte	**Object Name**	**Data Type**	**Value**
0	PSON	Boolean	0x01
1 – 7	Not Used	Not Used	0x00 0x00 0x00 0x00 0x00 0x00 0x00

Table 11 RPDO1

Byte 0 is the Enable / Disable flag to turn the output on and off. This is the only parameter required in this message.

Cob-ID: 0x00000206			
Byte	**Object Name**	**Data Type**	**Value**
0 - 3	Vout	Unsigned 32-bit Integer 1.52588E-05 scaling	0x00 0x00 0x0C 0x00 (this will set the output voltage to 12V)
4 - 7	Imax	Unsigned 32-bit Integer 1.52588E-05 scaling	0x00 0x00 0x64 0x00 (this will set the maximum current to be 100A)

Table 12 RPDO2

Chapter 8: List of Figures and Tables

Chapter 8 - List of Figures and Tables

8.1 Figures

8.2 Tables