Explore our Technologies

AC Motor Controller

HVLP-10/20 (Alpha & Beta)

Reference Manual V3.9

Document number: 177/52403

BorgWarner

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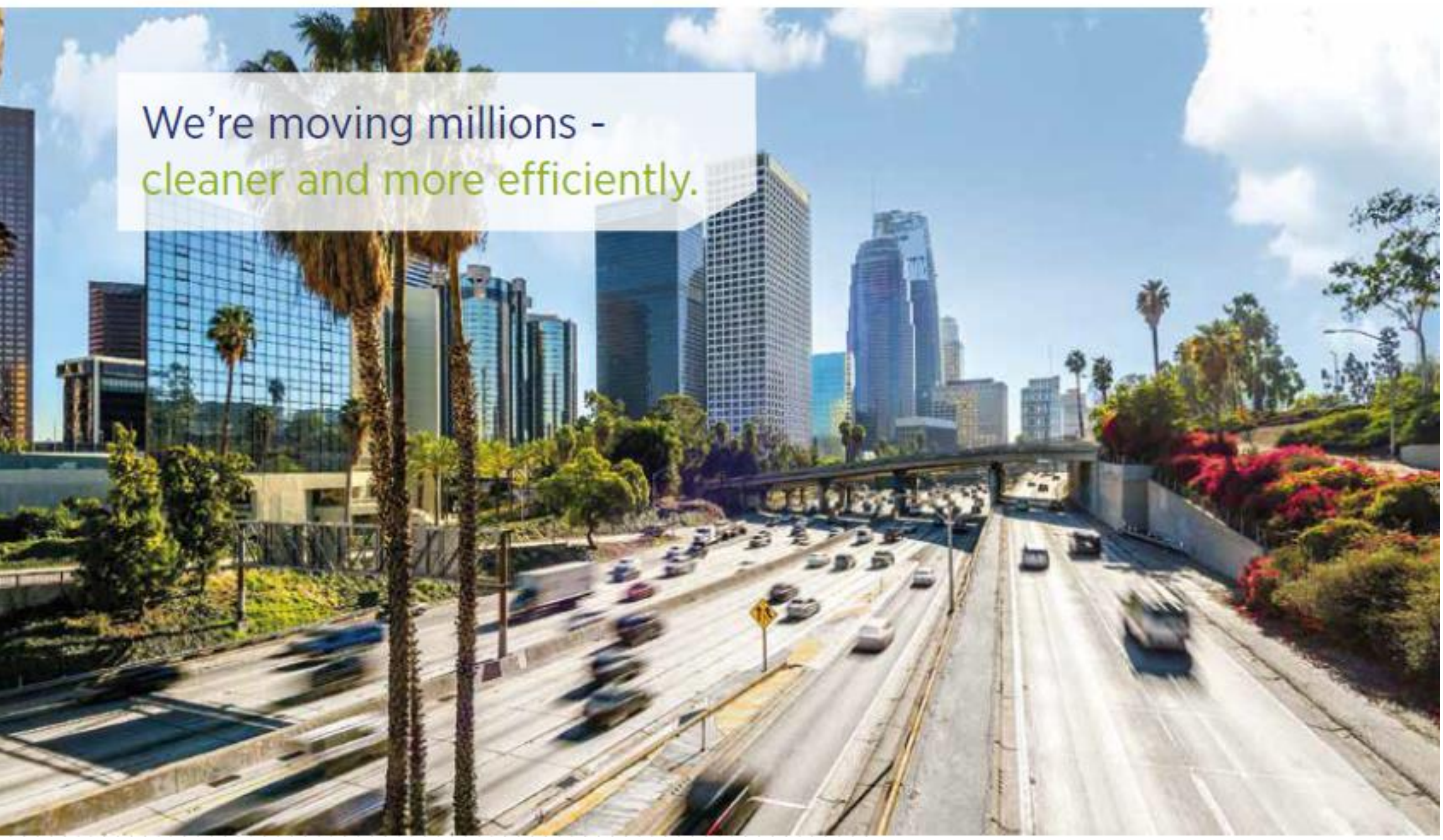
Hybrid

Electric



Chapter 1: Legal Disclaimer

Chapter 1 - Legal Disclaimer

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Important safety information

Electric vehicles (and their component parts such as motors, controllers and batteries) can be dangerous and cause severe damage to property and individuals if not handled correctly. All testing, fault-finding and parameter adjustment should be carried out by competent personnel. Incorrect parameter configuration or wiring can lead to an unsafe or dangerous system.

When setting up a new vehicle configuration, the vehicle should be immobilized with drive wheels raised on axle stands until the basic driver controls have been configured and the driver is able to stop the vehicle safely. Before this point, it is possible for full torque to be output from the motor, regardless of the driver demands.

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.

2.2 Purpose of this Manual

To support decision-makers, the first four chapters of this manual are intended to provide an overview of the HVLP-10/20 motor control 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 HVLP-10/20 motor controller. Guidance is provided to support engineers when configuring motor control systems, sizing a motor, 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 HVLP-10/20 manual applies to the Alpha and Beta variants of the HVLP motor controller. If you are not clear about which version of HVLP you are using, then contact your local BorgWarner representative. 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 Application Reference Manual provides important information on configuring motor control systems using HVLP-10/20 controllers as well as details on sizing and selecting system components, options and accessories.

This version of the manual applies to all controllers with BorgWarner part number:

634L10201 - ALPHA HVLP-10 air cooled AC controller 700VDC up to 10kW

634L10202 - BETA HVLP-10 air cooled AC controller 700VDC up to 10kW

634L20201 - ALPHA HVLP-20 liquid cooled AC controller 700VDC up to 20kW

634L20202 - BETA HVLP-20 liquid cooled AC controller 700VDC up to 20kW

The manual also presents important information about the HVLP product range.

2.2.3 Related documents

The following documents are available from BorgWarner or Authorized Distributors:

- DVT User Manual
- The HVLP Object Dictionary providing important information about CANopen communication and configuration with HVLP-10/20
- Application Notes for specific configuration:
    - H-Protocol
    - I-protocol
    - HVLP + D8 Line Contactor and Pre-Charge configuration
    - HVLP + D8 Mapping J1939 Items to VehApp
    - HVLP + D8 Motor Temperature Sensor configuration
    - HVLP + D8 + Gen5 Encoder configuration
    - V/f Induction Motor setup
    - HVLP + D8 Torque Conditioner
    - Vehicle EMC recommendations

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.

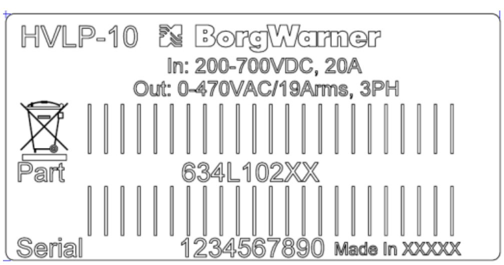


Figure 1 – Product Identification label (HVLP-10)

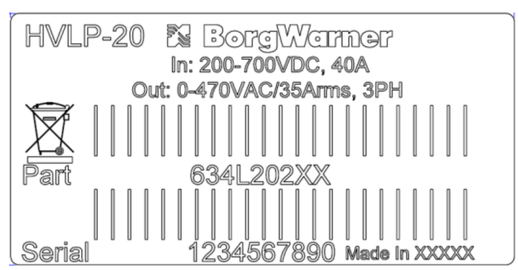


Figure 2 – Product identification label (HVLP-20)

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.

Table 1 – Conventions

2.6 Our Controllers - An Overview

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

The controller adapts its output current to suit the loading conditions and the ambient temperature in which it is operating - temporarily shutting down if necessary. As a safety feature, the controller will protect itself if the low voltage circuits are incorrectly wired.

Signal wiring and power connections are designed to be as simple and straight forward as possible.
Analogue and digital signal inputs and outputs are provided for switches, sensors, contactors, hydraulic valves and CAN communications.
The controller can be configured to share its I/O, share its results or take commands from other controllers or displays on the CAN bus.

Configuration and control of BorgWarner controllers is fully customizable.
However, for a bespoke solution, please contact us for further information.

Chapter 3: Specification

Chapter 3 - Specification

3.1 Electrical

3.1.1 Input voltage – Control supply

Nominal working voltage:	12V to 24V
Working voltage limits:	8V to 36V
Input protection:	Input protected against reverse connection of battery

Table 2 – Input voltage – control supply

3.1.2 Input voltage – DC Link supply

Nominal working voltage:	700V
Working voltage limits:	150V to 800V dc
Non-operational overvoltage limit:	850V dc
Maximum discharge current (power frame disabled)	5mA
Input protection:	User must ensure that reverse polarity protection is provided external to the controller, for example by control of the main line contactor.
Surge protection	User must provide a pre-charge circuit to limit inrush current when the supply is first turned on
Ground fault detection	User must ensure that ground fault protection is provided external to the controller, for example by control of the main line contactor.

Table 3 – Input voltage – High Voltage supply

3.1.3 Motor Output protection

Output current:	Reduced automatically from peak to continuous rating depending on the time a peak load is applied to the controller. Reduced automatically if the controller or motor is 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 HVLP-10/20 determines if valid output loads are present before applying drive current.

Table 4 – Motor output protection

Repetitive short circuits may damage the controller.

3.1.4 Output ratings

The rating achievable in a particular application must be checked.

Parameter	**HVLP10 (static air)[1]**	**HVLP10 (1m/sec)**	**HVLP20 (Liquid cooled)**
Continuous output current (A)	19[2]	21[2]	33[3]
Continuous output power @ 700V dc (kW)	11	13	22
Continuous output power @ 300V dc (kW)	4.5	5.5	9.5
Maximum output current (A) for 60s[2]	24	27	53
Stall output current (A) for 5s[2,4]	48	48	53

Table 5 – Output Ratings

Power outputs in the above tables are approximate maximums. The actual power achieved will depend on modulation index, power factor and motor efficiency.

Notes:

1. Static air operation requires convection over the heatsink, with the unit orientated vertically - see Orientation (page 35)
2. May require PWM frequency to be reduced
3. Limited by motor cable / connector
4. Stall currents stated are peak phase current, not rms.

3.1.5 Rating Graphs

For each test, four of the following five conditions are held at their nominal value and the remaining condition is varied. The conditions are:

- DC link voltage: 700 volts DC
- PWM switching frequency: 8 kHz with and without Bus Clamping Modulation
- Motor voltage: 65% - 70%
- Ambient temperature: 45°C
- Coolant (HVLP-20 only): 65°C input temperature, 50/50 glycol/water mixture at 6l/min flow rate
- Air flow: Static air conditions only (approx. 0.5m/s)

These results should be considered typical. There may be a variation in the output power achieved depending on the specific installation

3.1.5.1 HVLP10 Rating Graphs

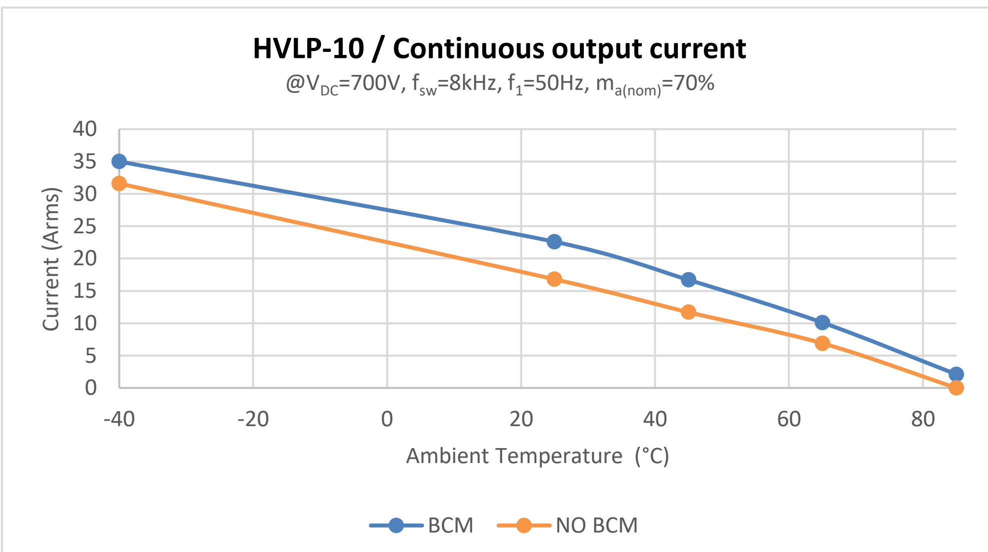


Figure 3 – HVLP10: Effect of Ambient Temperature on Rating

Conditions: DC link voltage: 700V DC, PWM frequency: 8kHz, Motor voltage: 70%

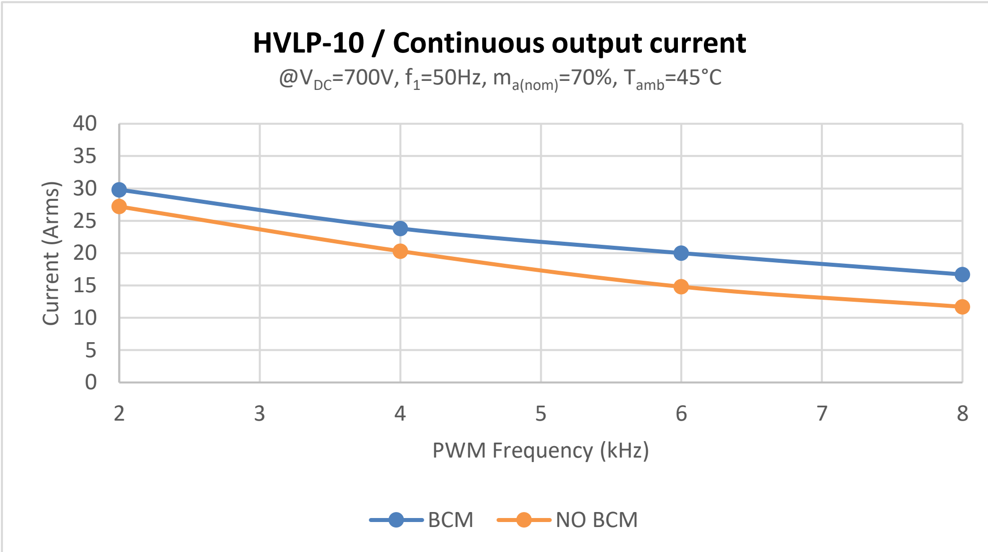


Figure 4 – HVLP10: Effect of PWM Frequency on Rating

Conditions: DC link voltage: 700V DC, Ambient temperature 45°C, Motor voltage: 70%

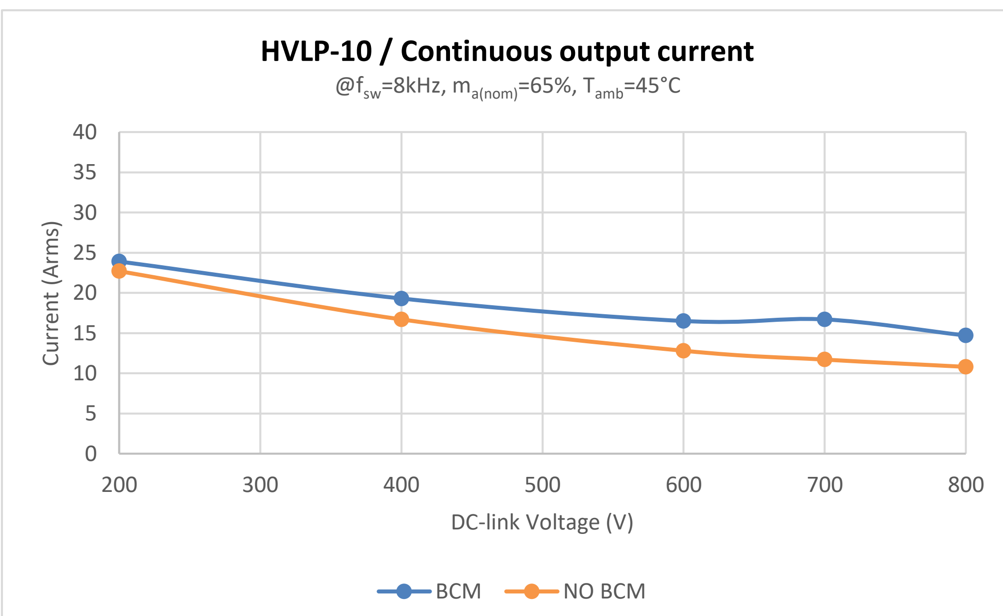


Figure 5 – HVLP10: Effect of DC-link Voltage on Rating

Conditions: PWM frequency: 8kHz, Ambient temperature 45°C, Motor voltage: 65%

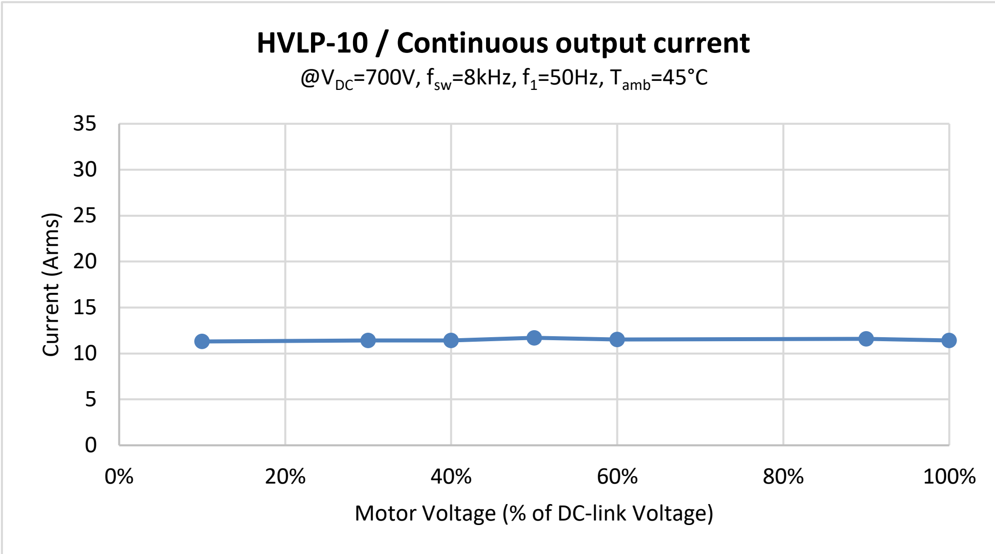


Figure 6 – HVLP10: Effect of Motor Voltage on Rating

Conditions: DC link voltage: 700V DC, PWM frequency: 8kHz, Ambient temperature 45°C

3.1.5.2 HVLP20 Rating Graphs

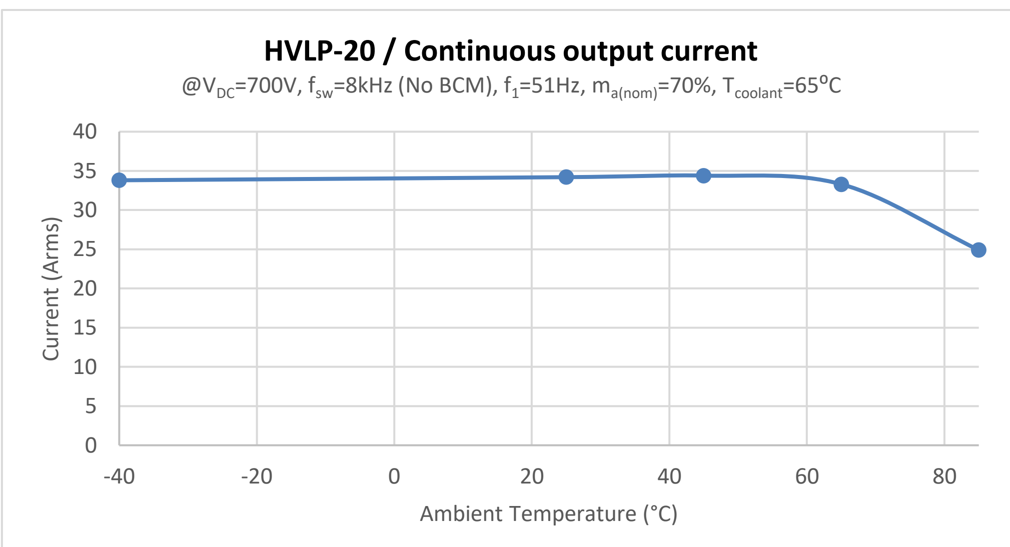


Figure 7 – HVLP20: Effect of Ambient Temperature on Rating

Conditions: DC link voltage: 700V DC, PWM frequency: 8kHz, Motor voltage: 70%, Coolant temperature: 65°C
Comment: Output current limited by motor cable below 65°C

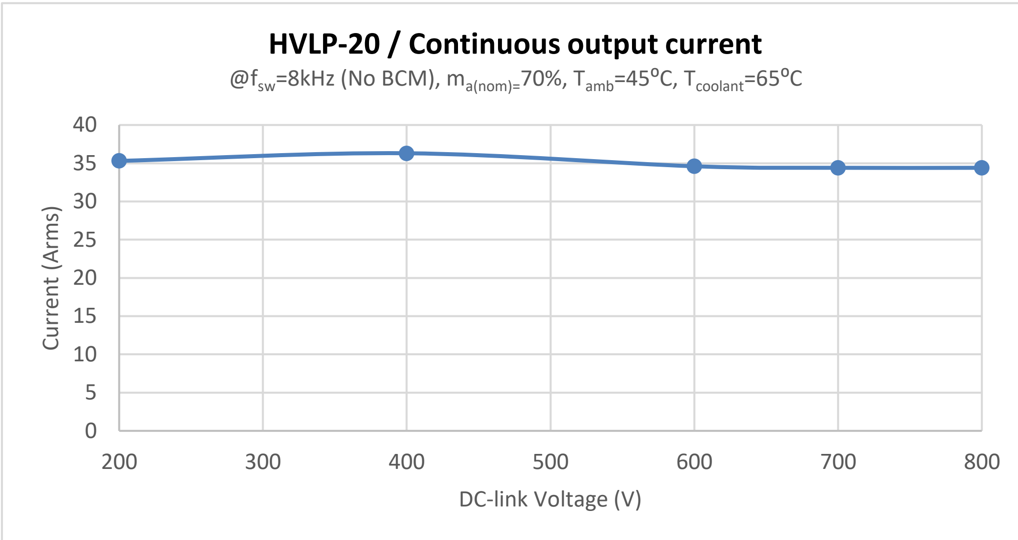


Figure 8 – HVLP20: Effect of DC-link voltage on Rating

Conditions: PWM frequency: 8kHz, Motor voltage: 70%, Ambient temperature: 45°C
Coolant temperature: 65°C
Comment: Output current limited by motor cable

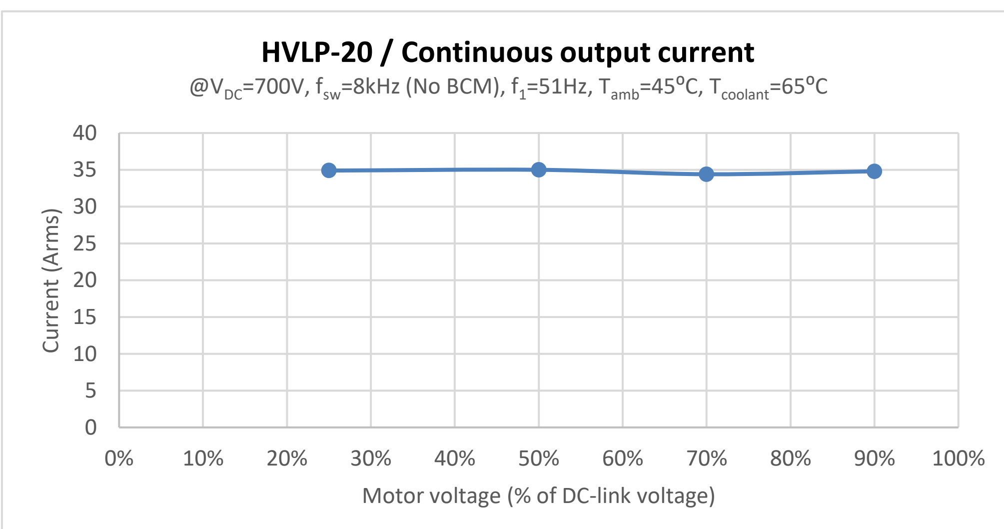


Figure 9 – HVLP20: Effect of Motor voltage on Rating

Conditions: DC link voltage: 700V DC, PWM frequency: 8kHz, Ambient temperature: 45°C
Coolant temperature: 65°C
Comment: Output current limited by motor cable

3.1.6 CAN interface

CAN protocol:	H-protocol and I-protocol are supported for motor control J1939 compatible CANopen supported for system configuration and diagnostics Physical layer uses ISO11898-2.
Baud rates supported:	1 Mbits/s (default), 500 kbits/s, 250 kbits/s, 125 kbits/s, 100 kbits/s and 50 kbits/s.

Table 6 – CAN interface

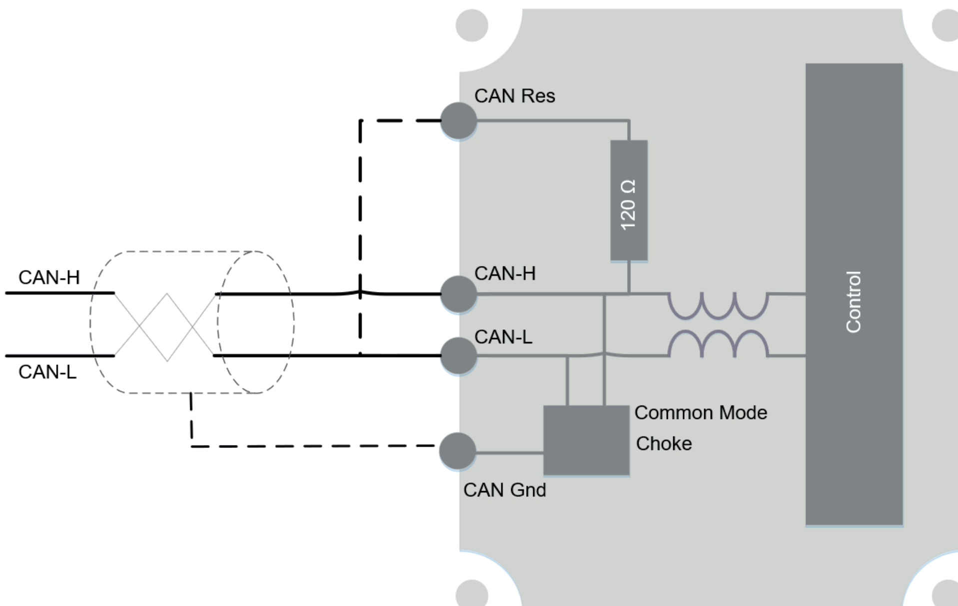


Figure 10 – Diagram showing CAN bus

3.1.7 Control inputs and outputs

Digital inputs:	4 digital switch inputs (software configurable polarity). Active low inputs < 2V Active high inputs > V_{KL15} – 2 V Current > 2mA when active (14V supply) Note: the digital input circuits have limited fault detection. With a switch input configured active low a short to supply can be detected, otherwise not, and with switch input configured active high a short to ground can be detected, otherwise not.
Analogue inputs:	4 general purpose inputs which can be used for 2-wire potentiometers or dual throttle type devices: • 0 to 10V input • 10-bit resolution • Input resistance > 50kΩ All analogue inputs can also be used as digital inputs. Analogue inputs must be referenced to analogue ground
Motor thermistor inputs:	2 motor thermistor inputs (only 1 for alpha variant). Thermistor (e.g. KTY84 or PT1000) can be connected between the analogue input and control 0V • Internal excitation for the thermistor • When configured with a KTY84: Measurement range will be -40°C to +200°C • Configurable to use a user defined characteristic. • Must be referenced to analogue ground
Digital high side outputs	2 short circuit protected active high outputs, powered from KL15 input supply On / off control of the output only, no PWM voltage or current regulation Continuous sink current = 2A Note: Short circuit protection is only effective if the KL30 supply is less than 36V
Analogue supply outputs	2 short circuit protected supply outputs. Output voltage can be selected to 5V or 10V Output1: Programmable Vcc, 100mA max Output2: Encoder supply, 200mA max

Motor commutation sensor inputs:	Quadrature AB encoder and resolver signal inputs provided for control of induction motors. UVW digital position sensor or sin-cos analogue position sensor or resolver inputs provided for control of permanent magnet synchronous motors. (refer to page 107 for alpha and beta variants' comparison) AB and UVW are digital inputs which can accommodate both open collector and push pull sensor output specifications. (circuity incorporates internal 1kΩ pullup resistor to the encoder supply) Encoder inputs must be referenced to encoder ground
Resolver excitation	Two outputs, Exc+ and Exc-, provide a fixed 10kHz excitation to a speed feedback resolver. Each output is 4V max pk-pk, 100mA, protected against short-circuit. Consult the 'Resolver' section in the System Design section of this document for important information about resolver feedback.

Table 7 – Control inputs and outputs

3.1.8 Isolation

The HVLP comprises logic circuits (12V or 24V) and the high voltage circuits connected to B+/B-. These two circuit blocks are galvanically isolated from each other, and from the chassis.

As defined by ISO 6469-3, the logic circuits are class A, and the power circuits class B. There is a reinforced safety barrier between the power circuits and the logic circuits, and basic insulation between the power circuits and the enclosure. See Figure 11 below.

The unit is not designed for direct grid connection. As is typical for an electric vehicle the high voltage battery and inverter must be galvanically isolated from the public mains supply.

Creepage and clearance is sufficient for operation up to a maximum altitude of 4000m, compliant with EN 60664.

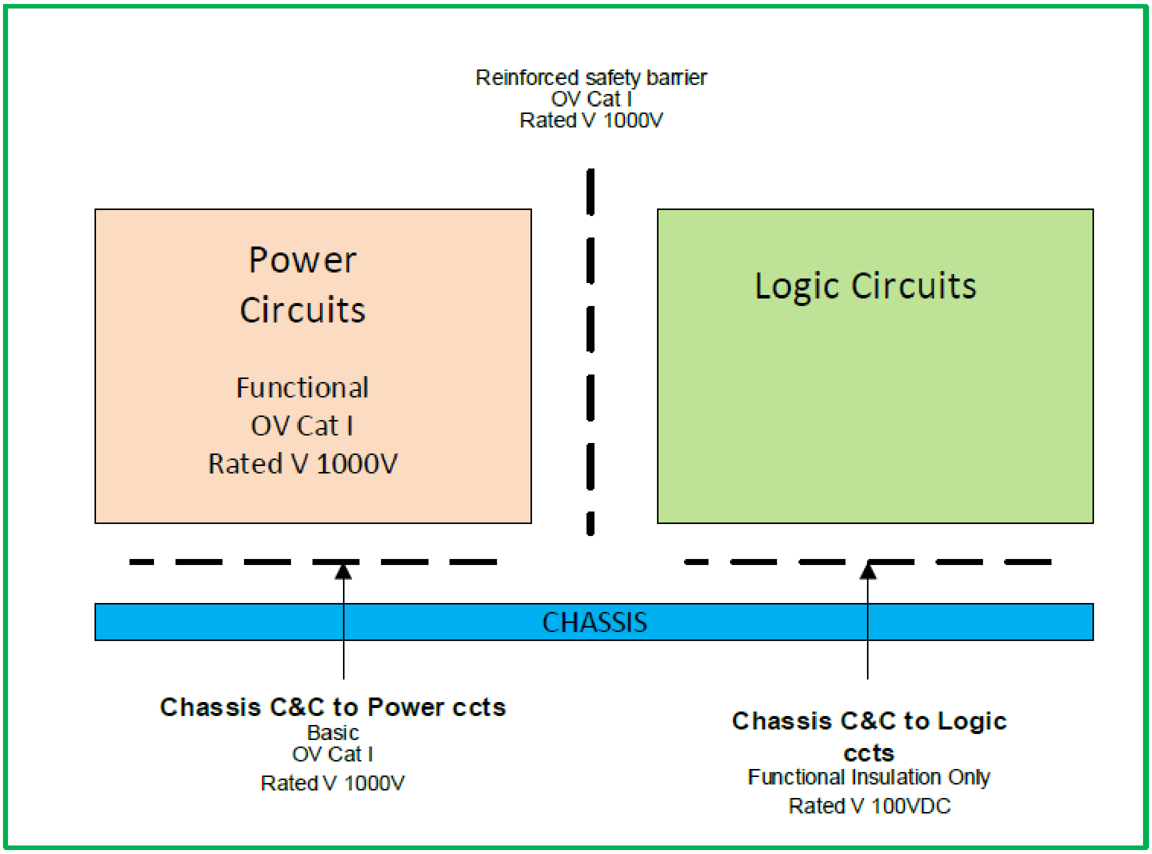


Figure 11 – Isolation Diagram

Power terminals to the case:	Withstands 2600 V ac[1]
Power terminals to control terminals	Withstands 3900 V ac[1]
Control terminals and CAN bus to the case	Withstands 100 V DC

Table 8 – Isolation

Notes:

1. Type test only

3.1.9 Regulatory compliance

The controller is designed to meet (**BETA variants only**) -

Safety regulations	EN 60664 Insulation coordination for low voltage equipment ISO 6469 Electrically propelled vehicles Safety specifications UNECE Reg 100 Electric vehicles - Construction & safety. (as part of a compliant system) ISO16230 (Draft) - Agricultural machinery and tractors. Safety of higher voltage electrical and electronic components and systems.
EMC regulations	Directive 2009/64/EC of the European Parliament and of the Council of 13 July 2009 on the suppression of radio interference produced by agricultural or forestry tractors (electromagnetic compatibility) UNECE reg 10 approval of vehicles with regard to electromagnetic compatibility
RoHS	Directive 2011/65/EU with amendment 2015/863/EU on the restriction of use of certain hazardous substances in electrical and electronic equipment (RoHS) with exemptions 6c, 7c-I, 7a
REACH	Regulation EC 1907/2006 Registration, Evaluation and Authorisation of Chemicals (REACH) ANNEX XVII with some exemptions.

Table 9 – Regulatory compliance (BETA variants only)

NOTE For the specification of HVLP ALPHA version please refer to the "Conditions of Use" document supplied with the product or available from BorgWarner.

3.2 Mechanical

3.2.1 Operating environment – HVLP-20 (Liquid Cooled)

Operating coolant temperature:	Liquid cooled; 50% water, 50% glycol Coolant temperature: -25°C to +65°C no current derating Coolant temperature: +65°C to +95°C and -40°C to -25°C with derating
Storage temperature range	-40°C to +100°C
Non-operation ambient temperature:	-10°C to +40°C (can be stored for up to 12 months in this ambient range)
Humidity:	95% at 40°C and 3% at 40°C
Ingress of dust and water:	Liquid cooled: IP67 and IP6K9K with connectors mated
Altitude	Designed to operate up to 4000m

Table 10 – Operating environment (HVLP-20)

3.2.2 Operating environment – HVLP-10 (Air Cooled)

Operating ambient temperature:	Air cooled: -30°C to +45°C no current derating +45°C to +85°C and -40°C to -30°C with derating
Non-operation ambient temperature:	Air cooled: -40°C to +85°C (can be stored for up to 12 months in this ambient range)
Humidity:	95% at 40°C and 3% at 40°C
Ingress of dust and water:	Air cooled: IP67 and IP6K9K with connectors mated
Altitude	Designed to operate up to 4000m

Table 11 – Operating environment (HVLP-10)

3.2.3 Shock and vibration

BETA variants only:

Thermal shock	EN60068-2-14, Test Na
Repetitive shock:	EN 60068-2-27, Test Ea 50 g peak 3 orthogonal axes, 3+ and 3– in each axis, 11 ms pulse width
Drop test:	EN 60068-2-32:1993 Test Ed: Free fall, appendix B, Table 1
Bump:	40 g peak, 6 ms, 1000 bumps in each direction repetition rate 1 to 3 Hz.
Vibration:	3 g, 5 Hz to 500 Hz
Random vibration:	20 Hz to 500 Hz, acceleration spectral density 0.05 g2/Hz (equivalent to 4.9 grms)

Table 12 – Shock and Vibration (BETA variant only)

NOTE For the specification of HVLP ALPHA version please refer to the "Conditions of Use" document supplied with the product or available from BorgWarner.

3.2.4 Controller Weight

HVLP-10 Air Cooled	3.7kg
HVLP-20 Liquid Cooled	2.3kg (dry weight)

Table 13 – Weight

3.2.5 Dimensions HVLP-10/20

3.2.5.1 HVLP-10 (Air Cooled)**:**

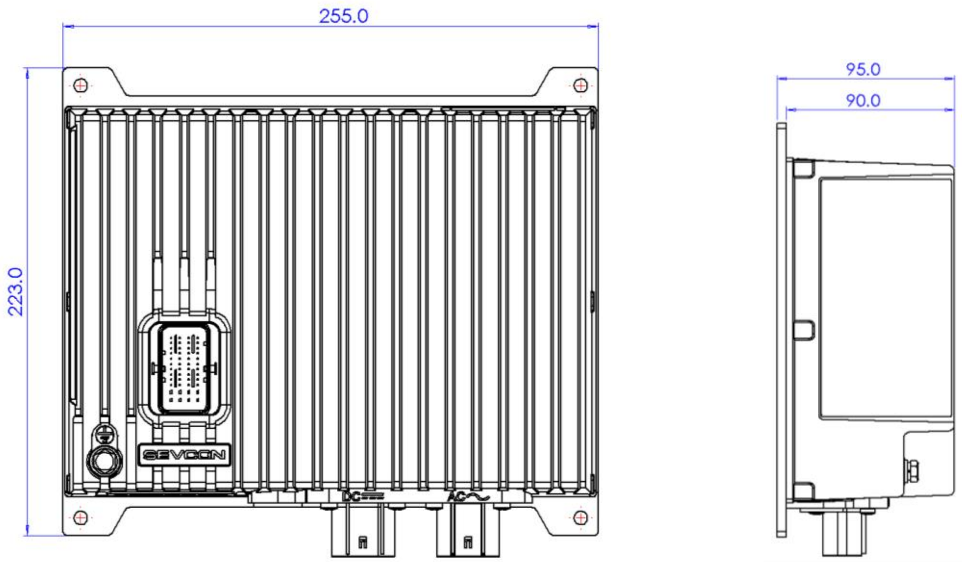


Figure 12 – HVLP-10 Dimensions

3.2.5.2 HVLP-20 (Liquid Cooled)

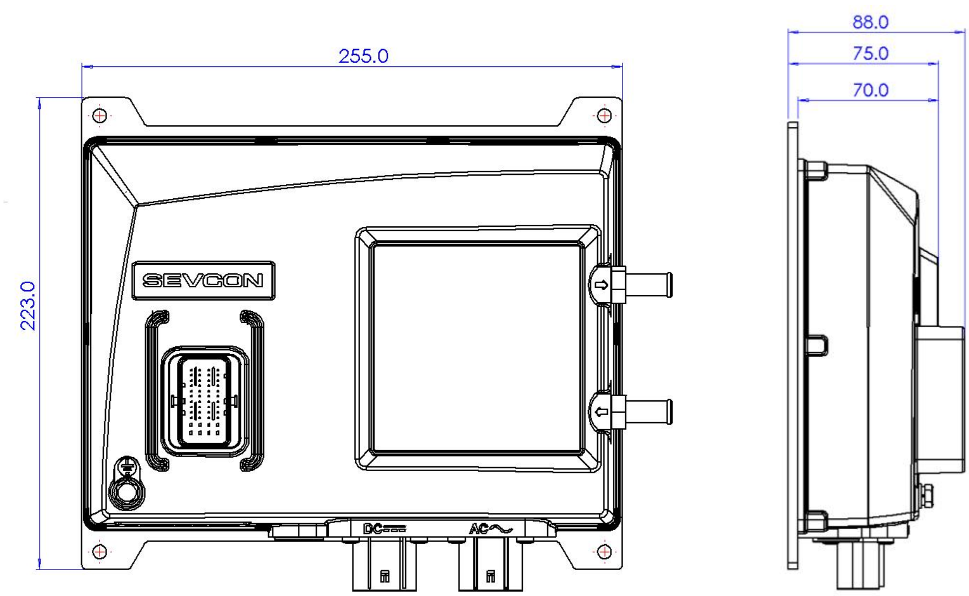


Figure 13 – HVLP-20 Dimensions

(Note 1 Above dimensions expected to be within +/-2.0mm)

(Note 2 Dimensions illustrated do not include allowance for connectors, cables and hoses)

Chapter 4: About the HVLP-10/20

Chapter 4 - About the HVLP-10 / HVLP-20

4.1 Introduction

BorgWarner HVLP-10/20 controllers are designed to control 3-phase AC induction motors and Permanent Magnet AC (PMAC) motors in battery and generator powered applications. A range of models are available to suit a wide number of applications and cooling regimes.

The controller has functions to limit the output load current depending on loading conditions, and ambient temperature in which it is operating (temporarily shutting down if necessary). It will also protect itself if the low voltage circuits are incorrectly wired.

Signal wiring and power connections have been designed to be as simple and straight forward as possible. Analogue and digital signal inputs and outputs are provided for switches, sensors, contactors, hydraulic valves and CAN communications. This I/O can also be mapped to the CAN bus for control by an external VCU.

Configuration and control of HVLP-10/20 is fully customizable using the latest version of BorgWarner’s DVT, a Windows based configuration software tool.

4.2 Standard features and capabilities

4.2.1 Intended use of the HVLP-10/20

The HVLP-10/20 motor controller can be used in many applications for auxiliary motor control, such as:

- Agricultural (tractors and implements)
- Light trucks
- Buses
- Marine

4.2.2 Available accessories

The following accessories are available from BorgWarner

- 184/22156 – 48 Way Molex plus 4M Cable for HVLP BETA used with Resolver sensor
- 184/22157 – 48 Way Molex plus 4M Cable for HVLP BETA used with SinCos or AB sensor
- 184/22158 – 48 Way Molex plus 4M Cable for HVLP BETA used V/F Induction setup
- 184/22145 – 2 Pin TE Plug & 4M Power Cable for HVLP (Battery DC)
- 184/22190 – 3 Pin TE Plug & 4M Power Cable for HVLP (Motor AC)
- DC-DC converters
- DVT - PC based configuration tool

4.3 Overview of a motor control application

The main components are shown in Figure 14. In this example there are two auxiliary motors. Communication between the controllers is achieved using the CAN H-protocol and I-protocol.

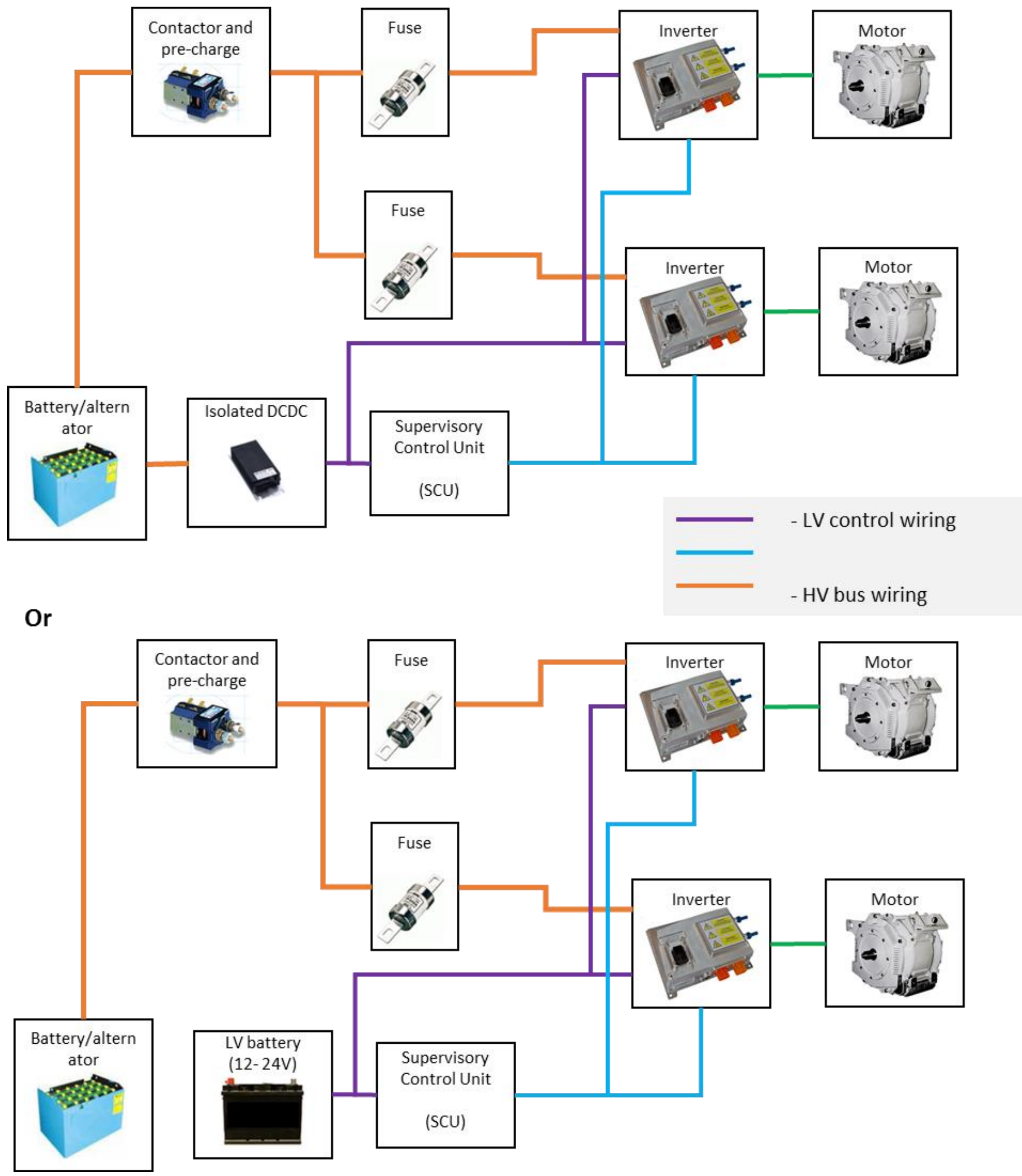


Figure 14 – Vehicle System Components

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

Pre-Charge functionality is not built into the HVLP product range. This must therefore be managed external to the HVLP unit.

4.4 Principles of operation

4.4.1 Functional description

The main function of HVLP-10/20 is intended to control the power to an ancillary motor (PMAC synchronous or AC Induction).

Measured phase currents and current demands are used as part of a closed-loop control system to calculate the necessary voltage demands for each phase of the motor.

4.4.2 Internal subsystems

The electrical circuit blocks within the HVLP-10/20 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 12V or 24V nominal power supply into the voltage required for the control logic
- Control logic – software runs on microprocessor circuits with input and output circuits for analogue and digital inputs, the motor encoder, CAN bus and digital outputs.

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 12/24V logic circuit ground. The CAN bus is connected to the control circuit ground. Additional ground connections (analogue ground, encoder ground, CAN ground) are provided to prevent voltage offsets caused by ohmic losses in the controller power ground connection from causing errors.

Do not connect the high voltage circuit to the 12/24V 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.

4.4.2.1 Power conversion section

The power conversion section of HVLP-10/20 employs a 6-switch IGBT bridge. 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, switching frequency and output torque may be 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.

4.4.3 Interfaces

In addition to its motor control functions, HVLP-10/20 offers many other functions designed to interface with electric systems. A variety of digital and analogue input sources are supported, as listed in ‘Signal connections’ on page 54.

On/off control of contactors is provided by HVLP-10/20. All I/O on the HVLP-10/20 controller is protected against short-circuit to the control logic positive and negative logic supply.

HVLP-10/20 connectivity and interoperability with other system devices (for example A VCU) using a CAN bus, the CANopen protocol, BorgWarner’s H-protocol (providing J1939 compatibility) for communications and I-protocol for I/O configuration is provided. In addition to in-service operation, the CANopen protocol allows the controller to be commissioned using the BorgWarner DVT tool.

Note: CANopen protocol is for commissioning and system diagnostics only and not for slave motor control operation.

4.4.4 General operation

The HVLP-10/20 controller functions as a motor control and I/O slave, as shown in figure below.

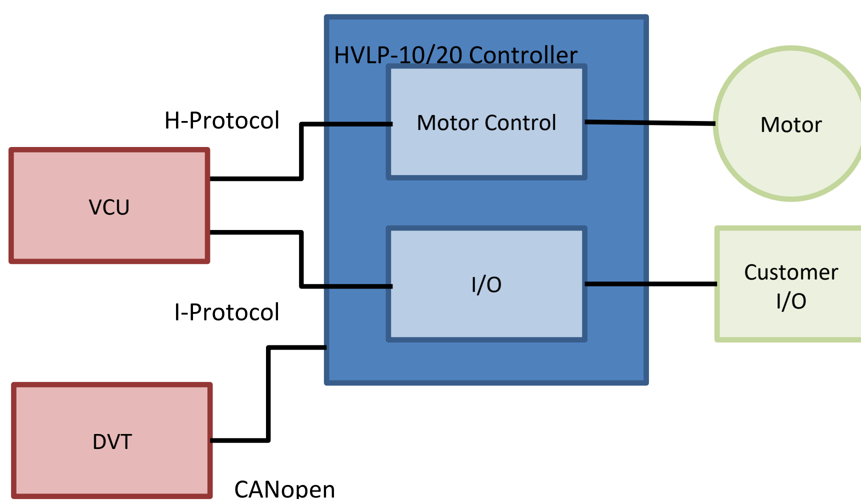


Figure 15 – HVLP-10/20 Controller

The H-protocol allows the VCU to control the state, torque demand, drive/braking torque limits, forward/reverse speed limits and discharge/recharge current limits to be controlled. Refer to BorgWarner's H-protocol documentation for more information.

I/O control is managed using the BorgWarner I-Protocol. Refer to the I-Protocol documentation for more information.

4.5 Safety and protective functions

4.5.1 General

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.

The battery or generator 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.

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 75 for controller discharge times.

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

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

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

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

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

⚠ Electric vehicles are subject to national and international standards of construction and operation which must be observed. It is the responsibility of the vehicle manufacturer to identify the correct standards and ensure that their vehicle meets these standards. As a major electrical control component, the role of the HVLP-10/20 motor controller should be carefully considered and relevant safety precautions taken. The HVLP-10/20 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.

4.5.2 On-Highway Vehicles

4.5.2.1 General

This applies to all on-highway vehicles, such as buses and trucks

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. The vehicle designer must ensure that the entire vehicle system complies with all international standards.

Chapter 5: Installation

Chapter 5 - Installation

5.1 Mounting HVLP-10/20

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. (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.

5.1.2 Orientation

5.1.2.1 HVLP-20 (Liquid Cooled)

The controller can be mounted in any orientation; however, BorgWarner recommend that the controller is located with the connectors pointing downwards as this gives the best environmental protection for the connectors.

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.

5.1.2.2 HVLP-10 (Air Cooled)

The controller must be located with the heatsink fins running vertically and preferably 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 85º 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.

5.1.3 Mounting hole pattern

HVLP-10 (Air Cooled) HVLP-20 (Liquid Cooled)

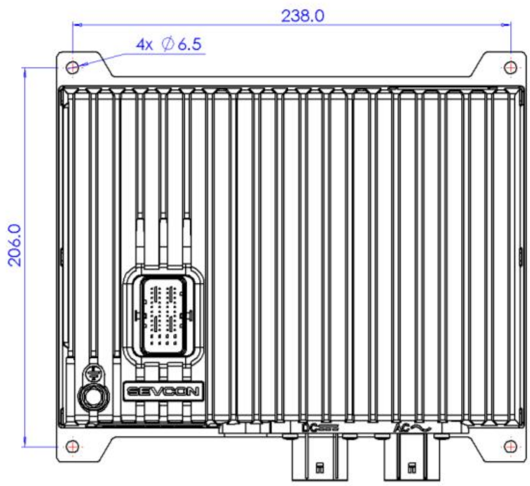


Figure 16 – HVLP-10 Mounting Hole Pattern

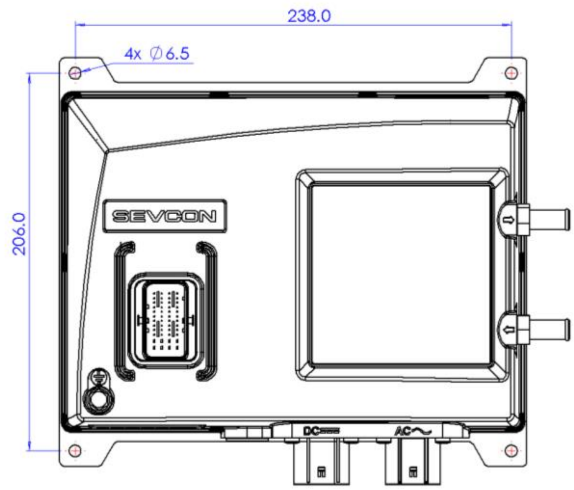


Figure 17 – HVLP-20 Mounting Hole Pattern

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

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.

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 HVLP-10/20 base plate and your mounting surface thickness.
- T hand-socket wrench or Allen key

Recommended torque setting: 10 Nm ± 2 Nm

5.2 HVLP-10/20 Cooling requirements

To ensure you get the maximum performance from your HVLP-10/20 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 24).

Caution must be practiced when touching the metal enclosure, as it can reach very hot temperatures (>70°C). For this reason, the unit is labelled with the following sign ("Caution, hot surface"), according to the IEC 61800-5-1 standard.

5.2.1 HVLP-10 – Air Cooling

- A minimum of 1m/sec air flow should be available to ensure rated power can be achieved.
- Fins should be kept clean and clear of any dirt and debris.
- Optimum performance will be achieved when mounted in a ventilated location with maximum possible airflow.

5.2.2 HVLP-20 – Liquid Cooling

- A 50/50 water-glycol mixture with a flowrate of 6 liter/minute should be sufficient to meet the ratings given in this manual.
- Maximum allowable coolant pressure of 1.0bar.
- See Figure 18 showing pressure drop vs flow rate

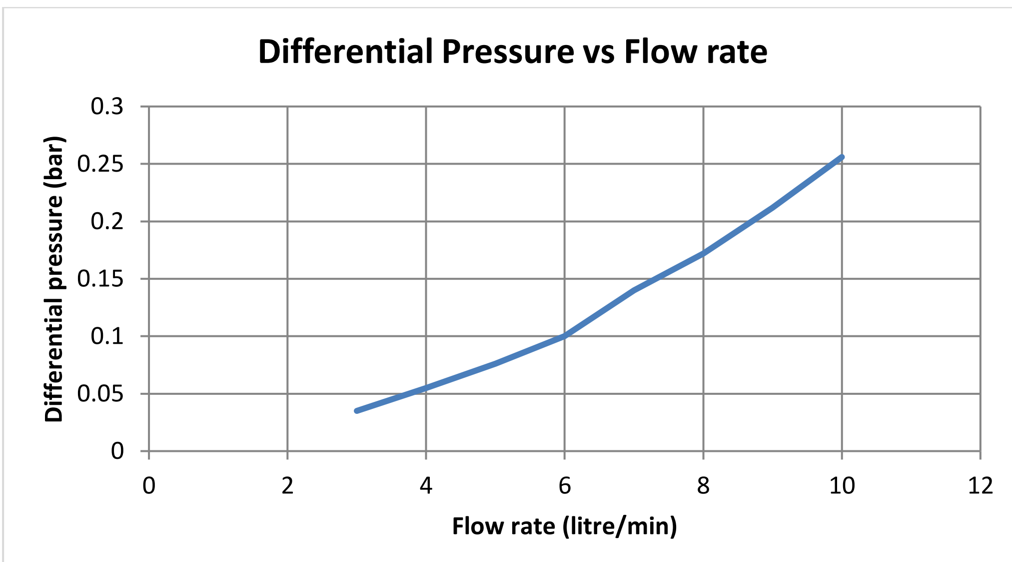


Figure 18 – Pressure drop vs. flow rate.

- The HVLP-20 comes fitted with two coolant hose tails. These are installed to the correct torque with a Loctite thread seal and should not be tampered with, changed or removed.
- The hose tails have a straight plain shank (Ø10.5mm) which should accommodate a 10mm (3/8”) hose possibly down to 8mm (depending upon the stiffness of the material).
- Arrows on the unit enclosure show the required flow direction.
- Coolant volume is approx. 40ml.
- Hoses should be provided with mechanical fixing with 200mm of the fitting.

5.3 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 minimize, 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.

5.3.1 General measures

5.3.1.1 Power cables

Use shielded 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 shield to the enclosure, ensuring that the various enclosures are linked with conductive braid to the vehicle chassis. Ensure that shields are terminated correctly within the HV connectors.

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.

Good practice when routing cables is to keep power cables at least 300mm from the signal cables.

5.3.1.2 Chassis protective earth connection

To comply with the touch current requirements in IEC 61800-5-1 (as HVLP touch current is > 3.5 mA_{ac}), the protective earth cable should be $10mm^2$, and terminated at the controller end with a suitable M6 ring terminal.

Alternatively, the DC input cable shield can be designated as a 2^{nd} protective earth and the protective earth cable can be $4mm^2$.

The unit is labelled with the following sign ("Caution") according to the IEC 61800-5-1 standard

and permanently marked on the metal enclosure, close to the protective earth bonding point, with the following sign ("Protective earth; protective ground") according to the same regulation.

It is essential that the chassis earth connection on the enclosure is connected to the vehicle or machine chassis using a short cable.

The controller is supplied with an M6 hex-head screw for this purpose.

The screw is supplied with a flat washer and spring washer which should all be refitted, and the screw tightened to 5Nm +/- 10%. See diagram below.

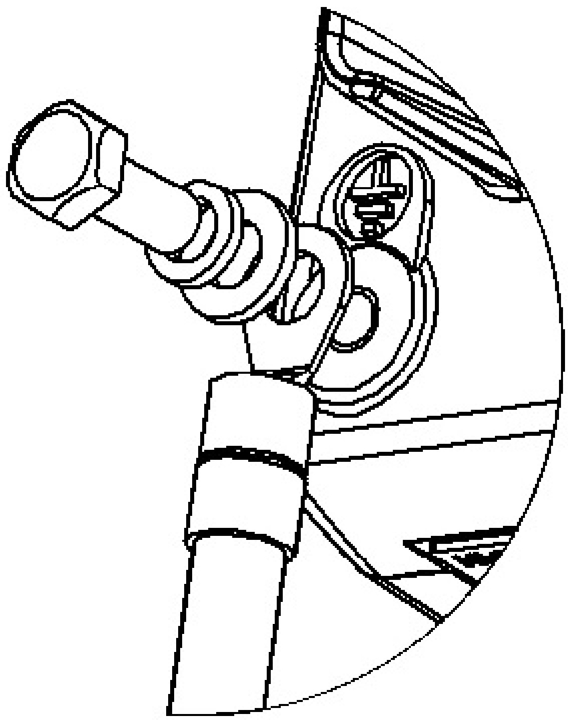


Figure 19 – Protective Earth Connection Assembly

WARNING: Failure to provide a correctly sized protective earth connection could result in an electric shock risk and non-compliance with international electrical safety regulations

The protective earth connection should have a maximum resistance of 0.1Ω when measured at 20A

Notes:

1. The high voltage cable shields should be regarded as EMC shields and are not a substitute for the protective earth connection described above
2. **The vehicle or machine is required to have a ground fault monitor (protection by automatic disconnection to comply with the requirements of section 6.3.3 for IT systems, IEC 60204-1: edition 5.1 2009.)**

5.3.1.3 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 shielded cable. Keep control wiring clear of power cables when carrying analogue information - for example, accelerator wiring and speed feedback. Tie all wiring securely and ensure it always follows the same layout.

5.3.2 Measures required for specific signals

5.3.2.1 High voltage battery/generator power cables

Use shielded cables. Cables should be as short as possible. Minimize the loop area of the B+ and B- wiring. A common mode ferrite choke may be required in some vehicle installations.

5.3.2.2 Motor power cables

Use shielded cables. Use metal cable glands and connect the shield of the cable to the gland. Cables should be as short as possible. Minimize the loop area of the M1 M2 M3 wiring. A common mode ferrite choke may be required in some vehicle installations.

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

The encoder cable must be as short as possible. A multi-core shielded 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 shield should be connected to the encoder ground terminal. Ensure that the shield does not connect the motor chassis back to the encoder ground terminal to avoid motor power cable current returning through the encoder cable shield.

For alpha variants, AB and UVW are differential signal inputs and therefore performance benefits may be seen with twisted pair shielded cables.

5.3.2.4 Motor encoder connection, resolver types

A resolver is a device consisting of a primary excitation winding (driven by a 10 kHz sinusoidal carrier signal generated by the HVLP-10/20) and two secondary windings where the carrier signal is modulated at the rotational frequency by the sine and cosine of the rotor angle.

The encoder cable must be as short as possible. Separate twisted pair shielded 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 shield should be connected to the encoder ground terminal. Ensure that the shields do not connect the motor chassis back to the encoder ground terminal to avoid motor power cable current returning through the encoder cable shield.

5.3.2.5 CAN bus

A multi-core shielded cable should be used. The inner cores must be twisted pairs. The twisted pair should be used for CANH and CANL. 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 HVLP-10/20 controller then the CAN ground on this node must be connected to the HVLP-10/20 controller control OV. The cable shield should be connected to the control OV terminal at the HVLP-10/20 controller. Ensure that CAN bus is terminated correctly for your system design.

5.3.2.6 Keyswitch (KL15 – KL30)

HVLP-10/20 offers 2 options for key switch control.

1. Combined ignition / battery control
2. Independent ignition / battery control

5.3.2.7 Combined ignition / battery control

Connect KL30 and KL15 together via a suitably rated key switch (10A DC) and fuse (7.5A recommended, 10A maximum) to the supply.

When key switch is opened, the controller switches off immediately.

5.3.2.8 Independent ignition / battery control

Connect KL30 via a fuse (5A recommended, 10A maximum) to the supply. Connect KL15 via a fuse (5A recommended, 10A maximum) and key switch to the supply. KL30 is active at all times. KL15 is the ignition switch.

The two digital outputs, which are rated at 2A each, are both powered from the KL15 supply. For this reason, the keyswitch should be rated at 5A.

5.3.2.9 Power up /down functionality

At power up, closing KL15 activates the controller as normal. The internal power supplies activate and the controller executes its start-up process and begins communicating on the CAN bus.

When KL15 is opened, torque is removed from the motor and both digital outputs turn off. The controller shutdown process is blocked until the motor speed has dropped below 500rpm, or 10s has elapsed. When these conditions are satisfied, the internal power supplies are deactivated and the controller shuts down. Closing KL15 again before the shutdown it activated will abort the shutdown process and normal operation will resume.

Both KL30 and KL15 inputs are 12V or 24V nominal. This wiring should be as short as possible. Minimize the loop area of the loop formed by the supply, OV return and any switches. Do not connect additional loads to these wires.

5.3.3 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 shielded cable for all control connections
- Install additional EMC shielding around the controller and/or 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

5.3.4 Problems to avoid

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

When using shielded cable beware of generating ground loops in which currents may be induced or which may cause noise currents to flow via unintended paths.

5.4 Connecting power cables

See also the section on EMC guidelines.

5.4.1 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 shielded power cables sized to suit the controller and application (see Table 18 below)
- TE HVA-280 high voltage connectors
- Cables are supplied pre-assembled to the connectors
- The DC Input cable includes a separate cable (shielded twisted pair) for the HVIL, and the two conductors for the high voltage supply, with an overall shield
- The motor output cable is also shielded, with 3 conductors.
- Ensure that minimum bend radius specifications are complied with for high voltage cables (typ. 5 x cable diameter)
- Ensure cables are clipped within 200mm of the connector location
- Try to prevent cables being flexed relative to the connector outlet as the connector seal can be damaged by this.

All external cables must have orange outer covering to comply with ECE Reg-100 or ISO 16230

Connector	Connector Location No	PCB Location	Wire
DC Link (184/22145) *(Figure 20 – DC-Link Connector Pin* Numbering*)* *Key Type B*	1	SK6 (positive)	Red, 4mm²
	2	SK7 (negative)	Blue, 4mm²
	3	High Voltage Interlock	Black, 0.5mm²
	4		
Motor (184/22190) *(*Figure 21 – Motor Connector Pin Numbering*)* *Key Type A*	1	SK8 (M1)	Brown, 2.5mm²
	2	SK9 (M2)	Black, 2.5mm²
	3	SK10 (M3)	Grey, 2.5mm²

Table 14 – High Voltage Connectors

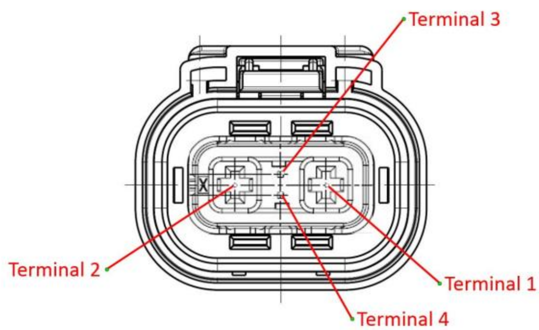


Figure 20 – DC-Link Connector Pin Numbering

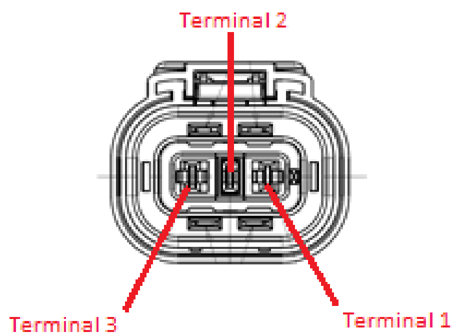


Figure 21 – Motor Connector Pin Numbering

Consider cable routing before making connections.

- Keep cable runs short
- Minimize current loops by keeping positive and negative cables as close together as possible.

5.4.2 Mating and Un-mating the HV connectors

5.4.2.1 Conditions for Mating and Un-mating the HV connectors

Connectors should be mated and unmated with the HV power off and in a safe condition, for example by opening a service plug and waiting for 5 minutes to allow for capacitor discharge.

Under no circumstances should the DC power connector be mated with the DC power supply live, as this would circumvent the pre-charge process and result in a very large inrush current

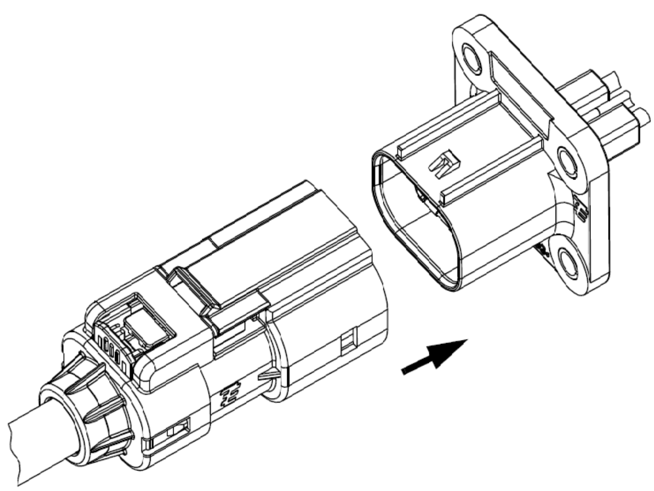
If it is essential to mate or un-mate either of the connectors with power applied, this must be done in a clean, dry environment. Attempting to mate or un-mate the connectors in a wet environment is extremely dangerous

5.4.2.2 Connector Mating

The text below is provided by TE Connectivity (see application specification 114-13305 revE)

- Align plug and header connectors as shown in Figure 22(A)
- Push the connector halves together fully until they stop (two clicks will be heard).
- Verify that the connectors are fully locked with a light tug and by visually verifying the thumb actuation pad has returned to its' upward position as shown in Figure 22(B).
- If present, push the red Connector Position Assurance (CPA) forward from the position shown in Figure 21B until it stops as shown in Figure 22(C).

^



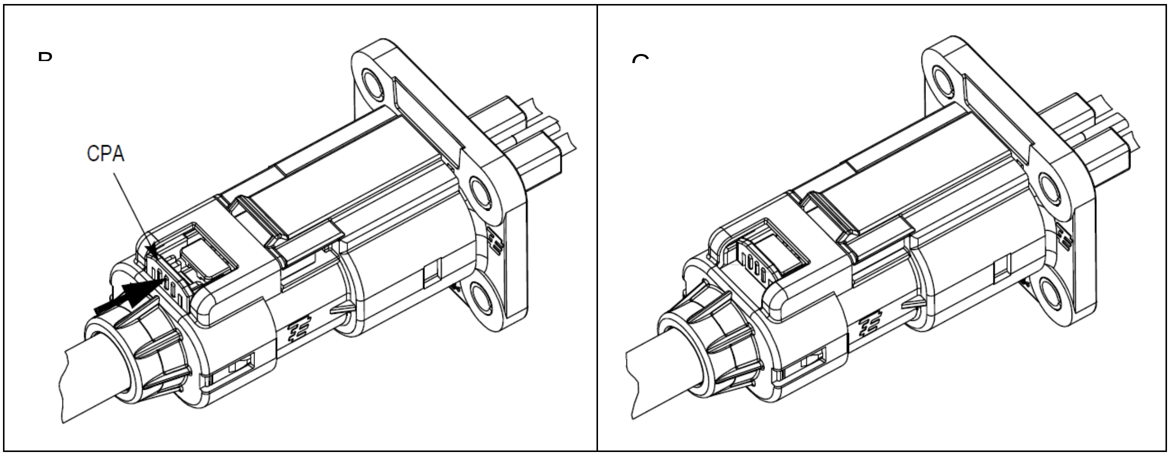


Figure 22 – Connector Mating

5.4.2.3 Connector Un-mating

1. If present, pull the red CPA back from the position as shown in Figure 23 (A) until it stops as shown in Figure 23 (B)
2. Fully depress the thumb actuation pad on the plug connector flexible latch (orange) shown in Figure 23 (B) and pull the plug connector back (~6.2 mm) into the intermediate position. See Figure 23 (C). At this point, in the case of the 2-terminal connector, the HVIL circuit has been opened, but the HV terminals are still making contact.

⚠ Do NOT pull on the wires.

3. Fully depress the actuation pad on the floating latch (black). See Figure 23 (D).
4. An alternate construction may not require a flat-bladed screwdriver. See Figure 23 (E).
5. Pull the plug connector until it is fully separated from the header. See Figure 23 (F)

⚠ Do NOT pull on the wires.

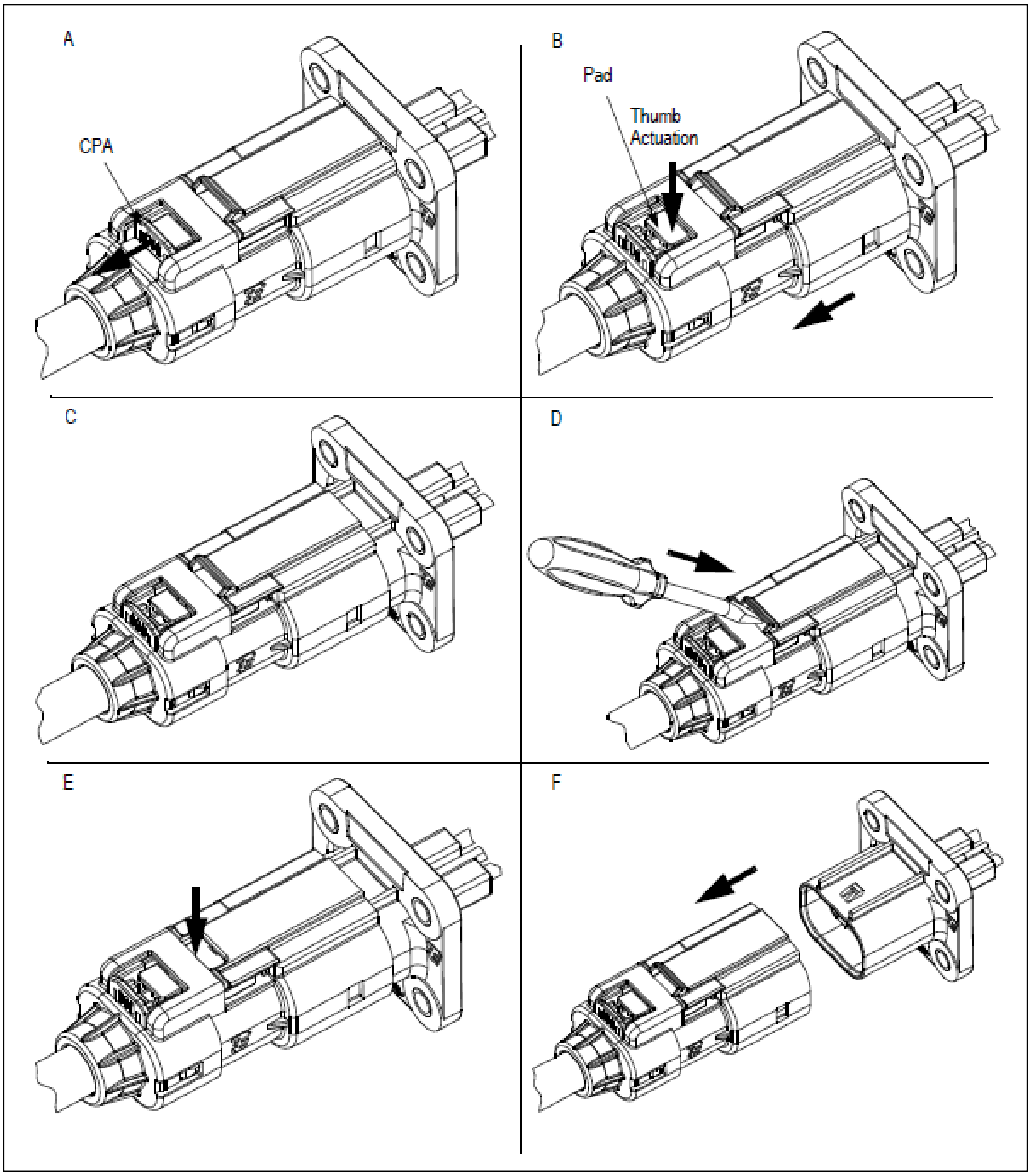


Figure 23 – Connector Un-mating

5.4.3 HVIL Wiring

The HVIL (High Voltage Interlock Loop) is included to prevent high voltages from being present on the vehicle or system in the event of a fault, or if a connection is unplugged.

Devices in the loop are expected to be connected in series, and if the loop opens the high voltage shall be switched off.

It is expected that the high voltage supply is switched off by an external system (e.g. the BMS) as normally the HVLP will not have control over this.

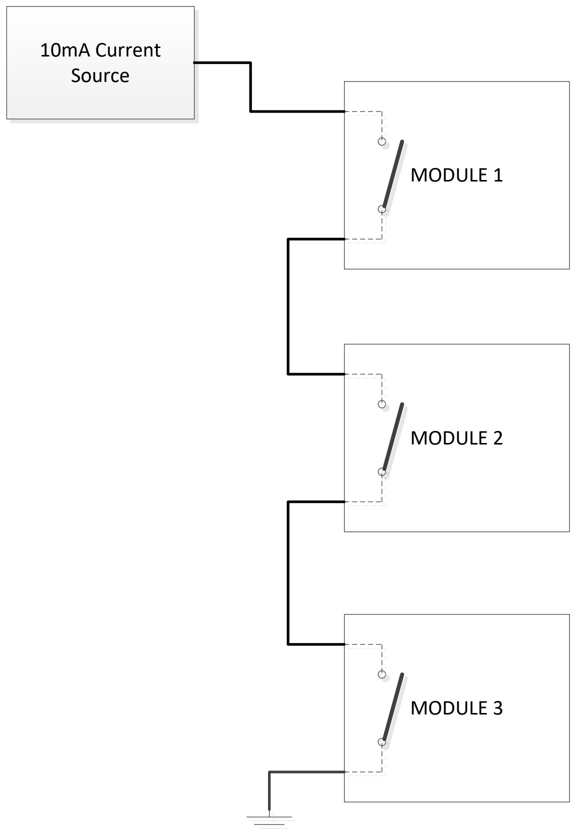


Figure 24 – Representative HVIL configuration

The HVLP-10/20 controller provides the following HVIL functions:

- HVIL I/O connector Inputs. Two inputs are provided on the I/O connector which can be connected either way round. They are used to monitor the HVIL. On alpha these are on pins G1 + G4 on beta these are on pins G4 + H4
- HVIL passive loop on high voltage DC input connector. If connected a part of the HVIL, the loop will be opened if the DC input connector in unplugged.
- HVLP alpha supports generating an HVIL source on pin K3. The current source is an isolated supply with a maximum output of 10mA. As HVLP is typically used as an auxiliary inverter, HVLP beta doesn’t include the HVIL current source, as it is expected that the main system components will generate the HVIL current.

NOTE: The HVIL connections on the high voltage DC connector are short circuited within the controller and there is no internal monitoring on the DC connector HVIL.

5.4.4 HVIL Specifications

- Two inputs on the I/O connector HVIL A, HVIL B are provided, on connector pins G1, G4 (alpha variant) and G4, H4 (beta variant)
- The circuit is designed to operate at 10mA, with a maximum allowed of 100mA, when activated. The typical voltage drop at 10mA is 0.5V
- Current can flow in the loop in either direction.
- The common mode voltage range can be 0V to +36V w.r.t KL31 (logic 0V)
- The circuit is galvanically isolated from other circuits. With an isolation voltage of at 40V with respect to KL31 (logic ground)
- The maximum permitted current is 100mA. The circuit is not protected from overcurrent.
- If the loop current magnitude falls below 3mA, the circuit detects loop "open"
- The loop is considered "closed" if the current is above 8mA.

5.4.4.1 HVIL Inputs

The HVIL logic inputs monitor the loop current and indicate to the controller whether the loop is correctly connected.

If the HVIL functionality is enabled it will provide the following functions:

- If the controller detects that the loop has been opened it will cause the motor to stop. This is implemented by forcing the torque to zero.

5.4.4.2 HVIL - Introduction to Switch Interlock (SIL)

The SIL (Switch Interlock) allows to configure additional inputs available in the controller to have an Interlock feature. Additionally, SIL allows the user to configure the cutback factor to be applied when the loop is broken.

The following table provides a list of the inputs that can be used with SIL:

Pin Name	IO Connector Pin	SIL Pin Identifier
DIN 1	J3	0
DIN 2	H3	1
DIN 3	J4	2
DIN 4	H4	3
AIN 1A	K1	4
AIN 1B	K2	5
AIN 2A	J1	6
AIN 2B	J2	7

Table 15 – HVLP alpha Switch Interlock (SIL) table

Pin Name	IO Connector Pin	SIL Pin Identifier
DIN 1	A3	1
DIN 2	B2	2
DIN 3	D2	3
DIN 4	D3	4
AIN 1	E1	5
AIN 2	F4	6
AIN 3	J4	7
AIN 4	K2	8

Table 16 – HVLP beta Switch Interlock (SIL) table

For more information on how to set up general input settings such as analogue input voltage ranges, digital input polarity, etc. refer to the dedicated section in this document.

5.4.4.3 HVIL/SIL Properties and Setup

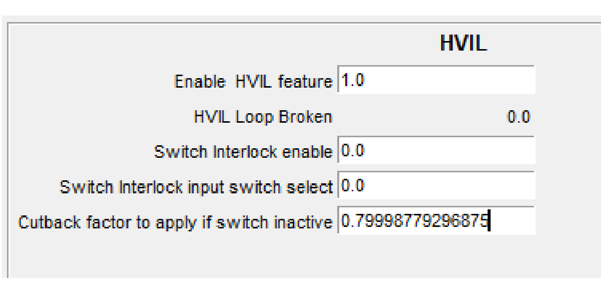
Object 0x3F02 is used to enable and configure HVIL and Switch Interlock (SIL) on the controller.

Object	Function
0x3F02, 1	Enables HVIL feature on the controller. Set to 1 to enable
0x3F02, 2	HVIL Loop Broken Indicator. Indicates the loop status of HVIL and SIL: 1 = loop opened (broken) 0 = loop closed
0x3F02, 3	Enables SIL feature on the controller. Set pin identifier
0x3F02, 4	Select input used as Switch Interlock
0x3F02, 5	Cutback factor if the Switch Interlock is active (0.0 – 1.0 range)

Table 17 – HVLP / SIL parameters

If either of the Interlocks is broken, there will be an Interlock loop broken fault and the cutback code reported in H-protocol will be 10 (assuming interlock is the highest priority cutback). Additionally, the HVIL Loop Broken Indicator object will report the loop as broken.

5.4.4.4 HVIL Setup



To enable HVIL in the controller set the object 0x3F02 sub index 1 to 1.

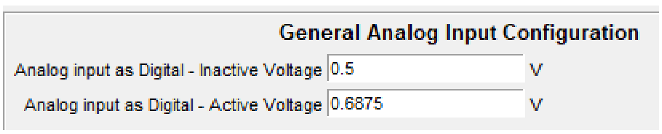
According to the above example, if the controller detects the HVIL loop as open, a torque cutback of 0.8 will be applied. Additionally, an “Interlock loop broken” fault (0x47C6) will be set. The fault will be cleared and the torque output will be resumed when the loop has been closed.

5.4.4.5 Switch Interlock (SIL) Setup

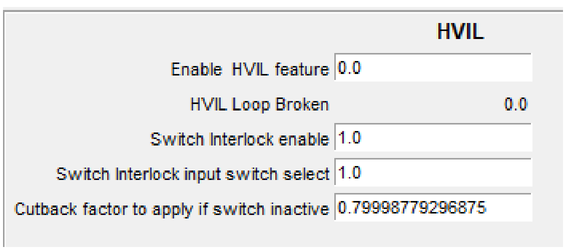
To enable SIL on the controller:

1. Enable SIL by setting object 0x3F02 sub index 3 to 1.
2. Select the desired input to be used as SIL. For more information on the possible values to set in this object refer to tables above (SIL Pin Identifier column).

NOTE: In order to use the analogue inputs, you need to configure the object 0x4690 according to the applications needs e.g. as shown in figure below.



3. Specify the cutback factor to be applied when the loop is broken (range between 0.0 and 1.0) in object 0x3F02 sub index 5.



According to the above example, if the controller detects the SIL loop as broken/open, a torque cutback of the factor specified in 0X3F02 sub 5 (0.8) will be applied. Additionally, an “Interlock loop broken” fault (0x47C6) will be set. The fault will be cleared and the torque output will be resumed when the loop has been closed.

In order for the controller to work as expected, only one of the features (either HVIL or SIL) can be enabled at a time.

5.4.5 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.

5.4.5.1 Motor Cable

The following table (Table 18) gives guidance on the motor output cable. The maximum current is determined from 30°C ambient with 60°C temperature rise on the cable surface. The controller incorporates software protection to prevent cable and connector terminals overheating.

HVLP-10/20 average (rms) current	Cable sizes	
	Metric	US (approx. equivalent)
33 A	2.5 mm^2	12AWG

Table 18 – Guidance on rating of shielded cable

Note that the standard cable (TE supplied with the 3 terminal HVA280) connector conductor area is 2.5mm2 as shown in the table above. Depending on the motor current the cable conductor temperature may be excessive. See Figure 14.

Anhang: Strombelastung, Dauerbestromung in Abhängigkeit zur Umgebungstemperatur
Rechnerische Ermittlung gemäß LV112-3 (Entwurf Mai 2009)

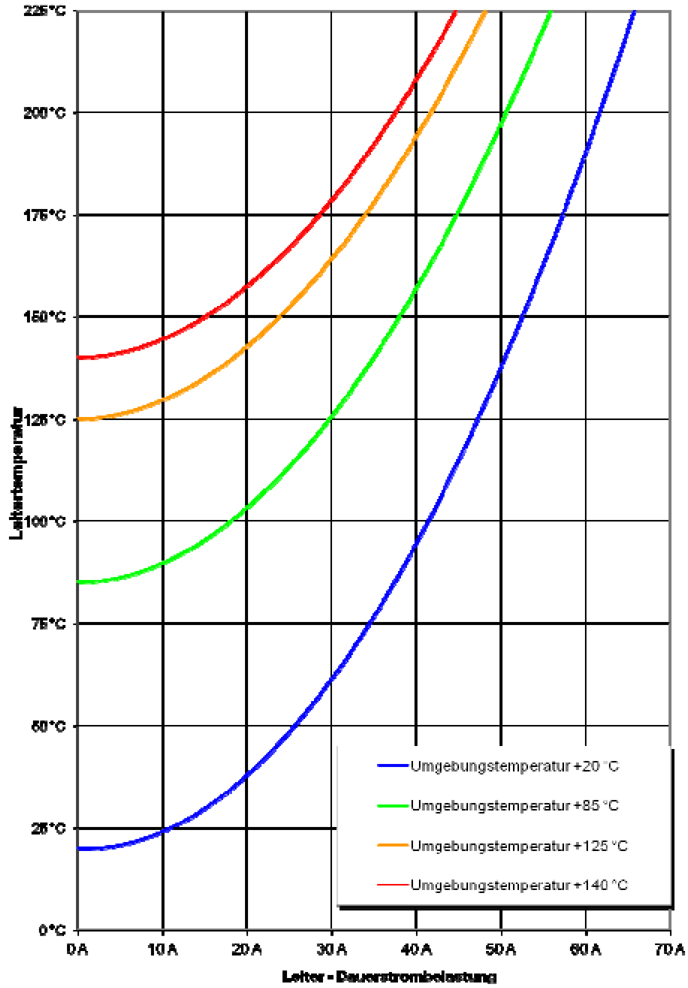


Figure 25 – Coroplast 2.5mm^2 Cable Conductor Temperature vs. Current

An additional factor is the current rating of the connector. At rated maximum operating temperatures (45°C ambient, 60°C coolant) the maximum continuous current that can be accommodated by the connector terminal is 33A. (Testing carried out in accordance with EN60512-5-2:2002). See figure 15 below which shows BorgWarner measurements and TE supplied data.

5.4.5.2 DC Cable / Connector

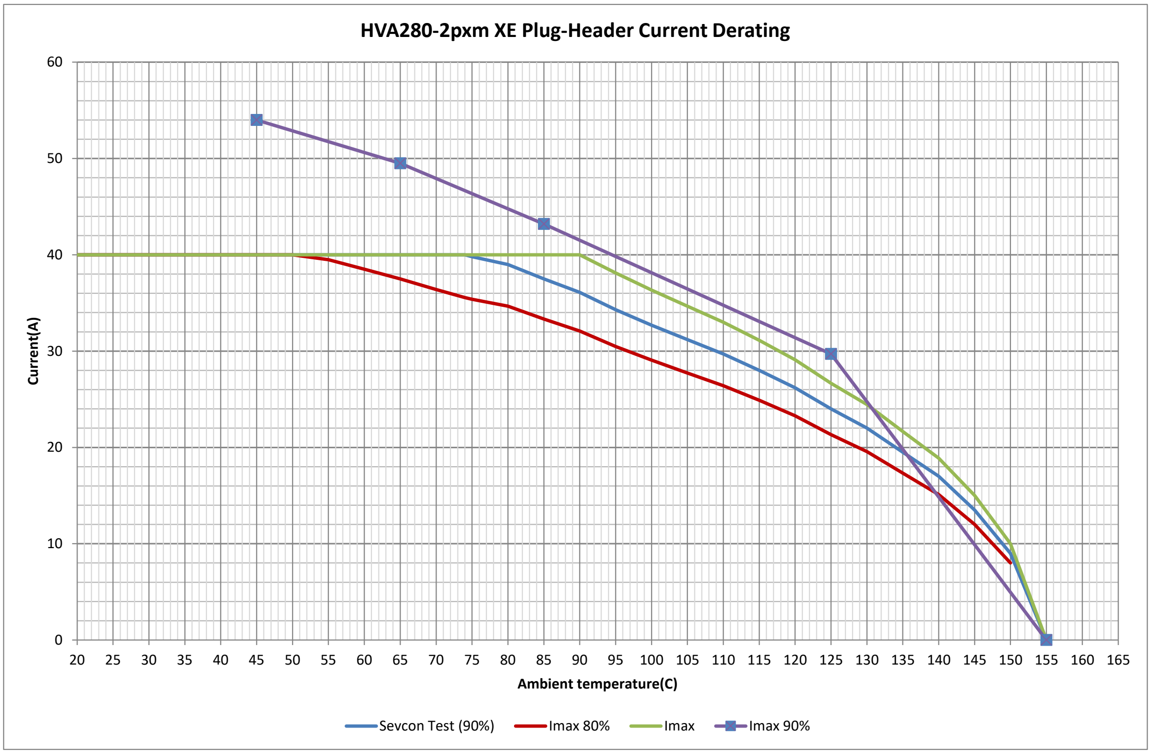


Figure 26 – DC Cable / Connector

5.4.6 Fuse rating and selection

See Auxiliary Components (page 66)

5.5 Signal wiring

Assemble your wiring harness using wire of the sizes recommended below. The use of twisted pair and in some cases twisted-shielded cables is recommended for the speed sensor and CAN bus wiring. See also the section on EMC Guidelines.

5.5.1 Signal wire sizes

Use wire between 0.5 mm^2 (20 AWG) and 1.5 mm^2 (16 AWG) for all signal wiring. Single twisted pair cable is readily available in 0.5 mm^2 (20 AWG).

5.5.2 CAN bus termination

If your system has more than one CAN node, connect the nodes in a ‘daisy chain’ arrangement and terminate the connections of the two end nodes with a 120Ω resistor. If the end node is a HVLP-10/20, link CAN_L and CAN_TERM on the customer connector, a 120Ω 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. See also the section on EMC.

5.6 Signal connections

Signal connections are made to HVLP-10/20 via a 48-way Molex CMC connector (Connector Molex P/N 64320-1311 and cover/strain relief Molex P/N 64320-1301)

Pins are numbered by rows 1 to 4 and columns A to M.

There are 8 ways for 1.5mm^2 cable and 40 ways for 0.5mm^2 cable.

To maintain IP rating, unused positions must be sealed with appropriate hardware (available from Molex for example P/N 64325-1010 and P/N 64325-1023).

Please consult Molex document AS-64319-002 for details of how to use the connector and part numbers for the pins and plugs which are required.

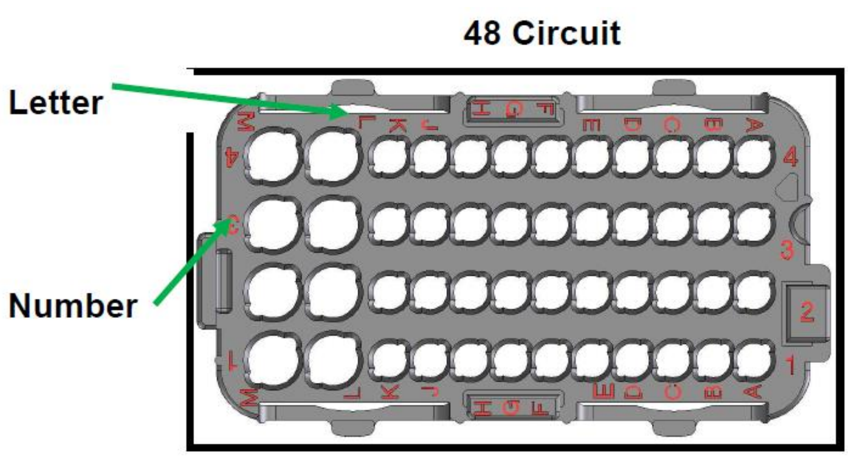


Figure 27 – Customer IO Connector

Name	Description	Molex P/N
Mating connector	Left wire output	64320-1311
Cover / strain relief		64320-1301
Terminal crimps 8 larger pins (columns L/M)	$1mm^2$ – $2mm^2$ wire size	64323-1039
Terminal crimps 40 smaller pins (columns A - K)	$0.75mm^2$ wire size	64322-1029
Sealing plugs 8 larger pins (columns L/M)	1.50mm cavity	64325-1023
Sealing plugs 40 smaller pins (columns A - K)	0.635mm cavity	64325-1010

Table 19 – Molex CMC connector part numbers

The majority of pins are protected against short-circuits to the control logic supply positive or negative terminals.

The HVLP-10/20 functions of each pin are shown in **Table 21** for HVLP alpha and **Table 22** for HVLP beta.

Digital Input	Impedance to 12/24V supply	Impedance to Control 0V
1, 2	10k	12k
3, 4	12k	10k

Table 20 – Impedance at Digital Input Pins

Configure the digital input switches as active-high (switched to +24V) or active-low (switched to 0V). See section Digital inputs for more details.

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

5.6.1 Alpha Variant

Alpha Variant					
Pin	Name	Type	What to connect	Maximum rating	Comment
A1	Resolver Cos Lo input	Analogue	Resolver type encoder	6V pk-pk	Shielded cables should be used for encoder connections. See Note 1
B1	Resolver Cos input	Analogue	Resolver type encoder	6V pk-pk	Shielded cables should be used for encoder connections. See Note 1
C1	Resolver Sin Lo input	Analogue	Resolver type encoder	6V pk-pk	Shielded cables should be used for encoder connections. See Note 1

Alpha Variant					
Pin	Name	Type	What to connect	Maximum rating	Comment
D1	Resolver Sin input	Analogue	Resolver type encoder	6V pk-pk	Shielded cables should be used for encoder connections. See Note 1
E1	Resolver excitation –	Analogue	Resolver type encoder	10kHz, 10V pk-pk (max)	Shielded cables should be used for encoder connections. See Note 1
F1	Resolver excitation +	Analogue	Resolver type encoder	10kHz, 10V pk-pk (max)	Shielded cables should be used for encoder connections. See Note 1
G1	Active HVIL input 1	HVIL	Interlock loop	0V to 36V	Connect to terminal 1 (of 2) of the HVIL loop. There is no polarity requirement for this (i.e. it can be connected either way round)
H1	Analogue 1 power supply +	Power	Programmable supply output	V = 5V or 10V I = 100mA max	V = +5V or +10V Set via I-protocol
J1	Pot. 2 wiper in (AIN2_A)	Analogue	From potentiometer 2(A) wiper.	V = 9.5V Zin = 50 kΩ	Suitable for potentiometers in the range 500Ω to 10 kΩ, or a voltage-output device 0V to 5V or 0V to 10V. Ensure that at least 0.5V margin exists between the maximum valid throttle and the wire-off threshold
K1	Pot. 1 wiper in (AIN2_A)	Analogue	From potentiometer 1(A) wiper.	V = 9.5V Zin = 50 kΩ	Suitable for potentiometers in the range 500Ω to 10 kΩ, or a voltage-output device 0V to 5V or 0V to 10V. Ensure that at least 0.5V margin exists between the maximum valid throttle and the wire-off threshold
L1	12-24 Supply Input (KL30)	Power	Logic power supply / battery via suitable fuse	V = 12V or 24V (nominal) I = 1A (max)	This input supplies power from the low voltage source for all the logic circuits. The unit cannot operate without KL30 supply.
M1	12-24 Supply Input (KL30)	Power	Logic power supply / battery via suitable fuse	V = 12V or 24V (nominal) I = 1A (max)	This input supplies power from the low voltage source for all the logic circuits. The unit cannot operate without KL30 supply.
A2	Encoder B input	RS422 Differential	AB differential encoder	10V or 5V (depending on configuration)	Shielded, twisted pair cables should be used for AB encoder connections. See Note 1
B2	Encoder A input	RS422 Differential	AB differential encoder	10V or 5V (depending on configuration)	Shielded, twisted pair cables should be used for AB encoder connections. See Note 1
C2	Encoder W input	RS422 Differential	UVW differential encoder	10V or 5V (depending on configuration)	Shielded, twisted pair cables should be used for UVW encoder connections. See Note 1
D2	Encoder V input	RS422 Differential	UVW differential encoder	10V or 5V (depending on configuration)	Shielded, twisted pair cables should be used for UVW encoder connections. See Note 1
E2	Encoder U input	RS422 Differential	UVW differential encoder	10V or 5V (depending on configuration)	Shielded, twisted pair cables should be used for UVW encoder connections. See Note 1

Alpha Variant					
Pin	Name	Type	What to connect	Maximum rating	Comment
F2	Encoder power supply +	Power	To the positive supply input of the encoder (AB, UVW or SinCos)	V = 5V or 10V I = 200mA	V = +5V or +10V Configured in software
G2	SIN input	Analogue	SIN/COS quadrature type encoder	V = 0V to 5V I = 10mA max	Shielded cables should be used for encoder connections. See Note 1
H2	Analogue input 3 (AIN3)	Analogue	To motor temperature thermistor	V = 13V I = 3mA Zout = 4.7kΩ	
J2	Pot. 2 wiper in (AIN2_B)	Analogue	From potentiometer 2(B) wiper.	V = 9.5V Zin = 50 kΩ	Suitable for potentiometers in the range 500Ω to 10 kΩ, or voltage-output device 0V to 5V or 0V to 10V. Ensure that at least 0.5V margin exists between the maximum valid throttle and the wire-off threshold
K2	Pot. 1 wiper in (AIN1_B)	Analogue	From potentiometer 1(B) wiper.	V = 9.5V Zin = 50 kΩ	Suitable for potentiometers in the range 500Ω to 10 kΩ, or voltage-output device 0V to 5V or 0V to 10V. Ensure that at least 0.5V margin exists between the maximum valid throttle and the wire-off threshold
L2	Control 0V	Power	Logic power supply ground connection	0V	
M2	Key switch in (KL15)	Wake-Up	From key switch via suitable fuse	V = 12V or 24V (nominal) I = 4A max	This input supplies power for the contactor outputs (if used) as well as providing a wakeup signal to the controller
A3	Encoder ~B input	RS422 Differential	AB differential encoder	10V or 5V (depending on configuration)	Shielded, twisted pair cables should be used for AB encoder connections. See Note 1
B3	Encoder ~A input	RS422 Differential	AB differential encoder	10V or 5V (depending on configuration)	Shielded, twisted pair cables should be used for AB encoder connections. See Note 1
C3	Encoder ~W input	RS422 Differential	UVW differential encoder	10V or 5V (depending on configuration)	Shielded, twisted pair cables should be used for UVW encoder connections. See Note 1
D3	Encoder ~V input	RS422 Differential	UVW differential encoder	10V or 5V (depending on configuration)	Shielded, twisted pair cables should be used for UVW encoder connections. See Note 1
E3	Encoder ~U input	RS422 Differential	UVW differential encoder	10V or 5V (depending on configuration)	Shielded, twisted pair cables should be used for UVW encoder connections. See Note 1
F3	Encoder ground (power supply negative)	Power	To the negative supply input (0V) of the encoder	V = 0V I = 200 mA	Shielded cables should be used for encoder connections. Connect the shield to this pin only along with the negative supply (AB, UVW or SinCos).

Alpha Variant					
Pin	Name	Type	What to connect	Maximum rating	Comment
G3	COS input	Analogue	SIN/COS quadrature type encoder	V = 0V to 5V I = 10mA max	Shielded cables should be used for encoder connections. See Note 1
H3	Digital Input 2	Digital	This can be active high or active low	V = 0V or V_{KL15} I = 2mA	Connect digital switch either to logic ground or logic supply (KL15)
J3	Digital Input 1	Digital	This can be active high or active low	V = 0V or V_{KL15} I = 2mA	Connect digital switch either to logic ground or logic supply (KL15)
K3	Active HVIL Source	HVIL	Interlock loop	0V to 36V I = 10mA max	Source for HVIL (loop). This output is a current limited isolated supply which can be used to originate the interlock system
L3	Digital High Side Contactor out 3	Output	To the high side of the contactor or valve coil.	I = 2A max V = V_{KL15}	This output provides a high side switched output to a load. Supplied from KL15 input
M3	Digital High Side Contactor out 4	Output	To the high side of the contactor or valve coil.	I = 2A max V = V_{KL15}	This output provides a high side switched output to a load. Supplied from KL15 input
A4	CAN Low	Comms	CAN bus Low signal	V = 5V	Maximum bus speed 1Mbits/sec
B4	CAN Low	Comms	CAN bus Low signal	V = 5V	Maximum bus speed 1Mbits/sec
C4	CAN termination	Comms	Link to pin B4 to connect an internal 120Ω termination resistor across the CAN bus.		Make the connection only if the controller is physically at the end of the CAN bus network
D4	CAN High	Comms	CAN bus High signal	V = 5V	Maximum bus speed 1Mbits/sec
E4	CAN High	Comms	CAN bus High signal	V = 5V	Maximum bus speed 1Mbits/sec
F4	CAN ground	Comms			Connect to the ground / shield of the CAN bus
G4	Active HVIL input 2	HVIL	Interlock loop	0V to 36V I = 10mA max	Connect to terminal 2 (of 2) of the HVIL loop. There is no polarity requirement for this (i.e. it can be connected either way round)
H4	Digital Input 4	Digital	This can be active high or active low	V = 0V or V_{KL15} I = 2mA	Connect digital switch either to logic ground or logic supply (KL15)
J4	Digital Input 3	Digital	This can be active high or active low	V = 0V or V_{KL15} I = 2mA	Connect digital switch either to logic ground or logic supply (KL15)
K4	Active HVIL Sink	HVIL	Interlock loop	0V to 36V I = 10mA max	Return signal for HVIL (loop). This output is a current limited isolated supply which can be used to originate the interlock system
L4	Control 0V	Power	Logic power supply ground connection	0V	

Alpha Variant					
Pin	Name	Type	What to connect	Maximum rating	Comment
M4	Control 0V	Power	Logic power supply ground connection	0V	

Table 21 – I/O Connector pin out and wiring information for Alpha variant

Note 1: Only one of UVW, AB, SIN/COS or resolver can be used. Configurable in software. Controller must be set up correctly for the motor speed feedback type.

5.6.2 Beta Variant

Beta Variant					
Pin	**Name**	**Type**	**What to connect**	**Maximum rating**	**Comment**
A1	Encoder power supply +	Power	To the positive supply input of the encoder (AB, UVW, SinCos)	V = 5V or 10V I = 200mA	V = +5V or +10V Configurable in software
B1	Resolver excitation +	Analogue	Resolver type encoder	10kHz, 10V pk-pk (max)	Shielded cables should be used for encoder connections. See Note 1.
C1	CAN termination	Comms	To terminate the CAN link pin C1 to C2. This connects an internal 120Ω termination resistor across the CAN bus.		Make the connection only if the controller is physically at the end of the CAN bus network
D1	Analogue 1 power supply +	Power	Programmable sensor supply output	V = 5V or 10V I = 100 mA max	V = +5V or +10V Set in I-protocol
E1	Analogue Input 1	Analogue	Analogue source (potentiometer, sensor)	V = 9.5V	Suitable for potentiometers in the range 500Ω to 10 kΩ, or voltage-output device. See Note 2.
F1	Encoder A / Sin input	Digital / Analogue	AB type encoder or Sin/Cos Encoder (AB has configurable 1kΩ pullup resistor to encoder supply)	SinCos: 0-5V AB: 0-10V	Shielded cables should be used for encoder connections. See Note 1.
G1	Motor Thermistor Input 1	Analogue	To motor temperature thermistor	V = 13V I = 3mA Zout = 4.7kΩ	KTY84 or PT1000 recommended. Connect thermistor between G1 pin and logic ground
H1	Encoder V input	Digital	UVW type encoder (internal 1kΩ pullup resistor to encoder supply)	UVW: 0-10V	Shielded cables should be used for encoder connections. See Note 1.
J1	Key switch in (KL15)	Wake-Up	From key switch via suitable fuse	V = 12V or 24V (nominal) I = 4A max	This input supplies power for the contactor outputs (if used) as well as providing a wakeup signal to the controller

Beta Variant					
Pin	**Name**	**Type**	**What to connect**	**Maximum rating**	**Comment**
K1	Encoder W input	Digital	UVW type encoder (internal 1kΩ pullup resistor to encoder supply)	UVW: 0-10V	Shielded cables should be used for encoder connections. See Note 1.
L1	12-24 Supply Input (KL30)	Power	Power Supply via suitable fuse	V = 12V or 24V (nominal) I = 1A (max)	This input supplies power from the low voltage source for all the logic circuits. The unit cannot operate without KL30 supply
M1	12-24 Supply Input (KL30)	Power	Power Supply via suitable fuse	V = 12V or 24V (nominal) I = 1A (max)	This input supplies power from the low voltage source for all the logic circuits. The unit cannot operate without KL30 supply
A2	CAN High	Comms	CAN bus high signal	V = 5V	Maximum bus speed 1 Mbits/sec
B2	Digital Input 2	Digital	This can be active high or active low	V = 0V or V_{KL15} I = 2mA	Connect digital switch either to logic ground or logic supply (KL15)
C2	CAN Low	Comms	CAN bus low signal	V = 5V	Maximum bus speed 1 Mbits/sec
D2	Digital Input 3	Digital	This can be active high or active low	V = 0V or V_{KL15} I = 2mA	Connect digital switch either to logic ground or logic supply (KL15)
E2	Encoder U input	Digital	UVW type encoder (internal 1kΩ pullup resistor to encoder supply)	UVW: 0-10V	Shielded cables should be used for encoder connections. See Note 1.
F2	No connection				
G2	Analogue Input Ground	Ground	Ground return and shield for analogue inputs	V = 0V I = 200 mA	**This pin is not protected from a short to KL15/KL30**
H2	No connection				
J2	Encoder B / Cos input	Digital / Analogue	AB type encoder or Sin/Cos Encoder (AB has configurable 1kΩ pullup resistor to encoder supply)	SinCos: 0-5V AB: 0-10V	Shielded cables should be used for encoder connections. See Note 1.
K2	Analogue Input 4	Analogue	Analogue source (potentiometer, sensor)	V = 9.5V	Suitable for potentiometers in the range 500Ω to 10 kΩ, or voltage-output device
L2	No connection				
M2	No connection				
A3	Digital Input 1	Digital	This can be active high or active low	V = 0V or V_{KL15} I = 2mA	Connect digital switch either to logic ground or logic supply (KL15)

Beta Variant					
Pin	**Name**	**Type**	**What to connect**	**Maximum rating**	**Comment**
B3	Resolver excitation -	Analogue	Resolver type encoder	10kHz, 10V pk-pk (max)	Shielded cables should be used for encoder connections. See Note 1.
C3	CAN ground	Power	To the ground / shield of the external CAN bus		**This pin is not protected from a short to KL15/KL30**
D3	Digital Input 4	Digital	This can be active high or active low	V = 0V or V_{KL15} I = 2mA	Connect digital switch either to logic ground or logic supply (KL15)
E3	Resolver Cos input	Analogue	Resolver type encoder	6V pk-pk	Shielded cables should be used for encoder connections. See Note 1.
F3	Resolver Cos Lo input	Analogue	Resolver type encoder	6V pk-pk	Shielded cables should be used for encoder connections. See Note 1.
G3	Motor Thermistor Input 2	Analogue	To motor temperature thermistor	V = 13V I = 3mA Zout = 4.7kΩ	KTY84 or PT1000 recommended. Connect thermistor between G3 pin and logic ground
H3	Resolver Sin input	Analogue	Resolver type encoder	6V pk-pk	Shielded cables should be used for encoder connections. See Note 1.
J3	Resolver Sin Lo input	Analogue	Resolver type encoder	6V pk-pk	Shielded cables should be used for encoder connections. See Note 1.
K3	Digital High Side Contactor Out 3	Output	To the high side of a contactor or valve coil.	I = 2A max V = V_{KL15}	This output provides a high side switched output to the load
L3	No Connection				
M3	No Connection				
A4	CAN High	Comms	CAN bus high signal	V = 5V	Maximum bus speed 1 Mbits/sec
B4	Encoder power supply ground	Power	To the negative supply input of the encoder (AB, UVW or SinCos). Also connect to encoder/resolver shield.	V = 0V I = 200mA	Connect the encoder shield to this pin only along with the negative supply. **This pin is not protected from a short to KL15/KL30**
C4	CAN Low	Comms	CAN bus low signal	V = 5V	Maximum bus speed 1 Mbits/sec
D4	No Connection				
E4	No Connection				
F4	Analogue Input 2	Analogue	Analogue source (potentiometer, sensor)	V = 9.5V	Suitable for potentiometers in the range 500Ω to 10 kΩ, or voltage-output device. See Note 2
G4	Active HVIL input 1	HVIL	Interlock loop	0V to 36V	Connect to terminal 1 (of 2) of the HVIL loop. There is no polarity requirement for this (i.e. it can be connected either way round)

Beta Variant					
Pin	**Name**	**Type**	**What to connect**	**Maximum rating**	**Comment**
H4	Active HVIL input 2	HVIL	Interlock loop	0V to 36V	Connect to terminal 2 (of 2) of the HVIL loop. There is no polarity requirement for this (i.e. it can be connected either way round)
J4	Analogue Input 3	Analogue	Analogue source (potentiometer, sensor)	V = 9.5V	Suitable for potentiometers in the range 500Ω to 10 kΩ, or voltage-output device. See Note 2
K4	Digital High Side Contactor Out 4	Output	To the high side of a contactor or valve coil.	I = 2A max $V = V_{KL15}$	This output provides a high side switched output to a load
L4	Control 0V	Power	Logic power supply ground connection	0V	
M4	Control 0V	Power	Logic power supply ground connection	0V	

Table 22 – I/O Connector pin out and wiring information for Beta variant

Note 1: Only one of UVW, AB, SIN/COS or resolver can be used. Configurable in software. Controller must be set up correctly for the motor speed feedback type.

Note 2: Ensure that at least 0.5V margin exists between the maximum valid throttle and the wire-off threshold

5.6.3 Control 0V Connections

The control 0V connections (L4, M4) should be connected to the vehicle or machine chassis as close to the controller as possible.

Chapter 6: System design

Chapter 6 - System Design

6.1 Selecting the HVLP-10/20 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 HVLP-10/20 controller are described below.

6.1.1 Circuit configuration

A basic single controller configuration (Figure 28 and Figure 29) 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.

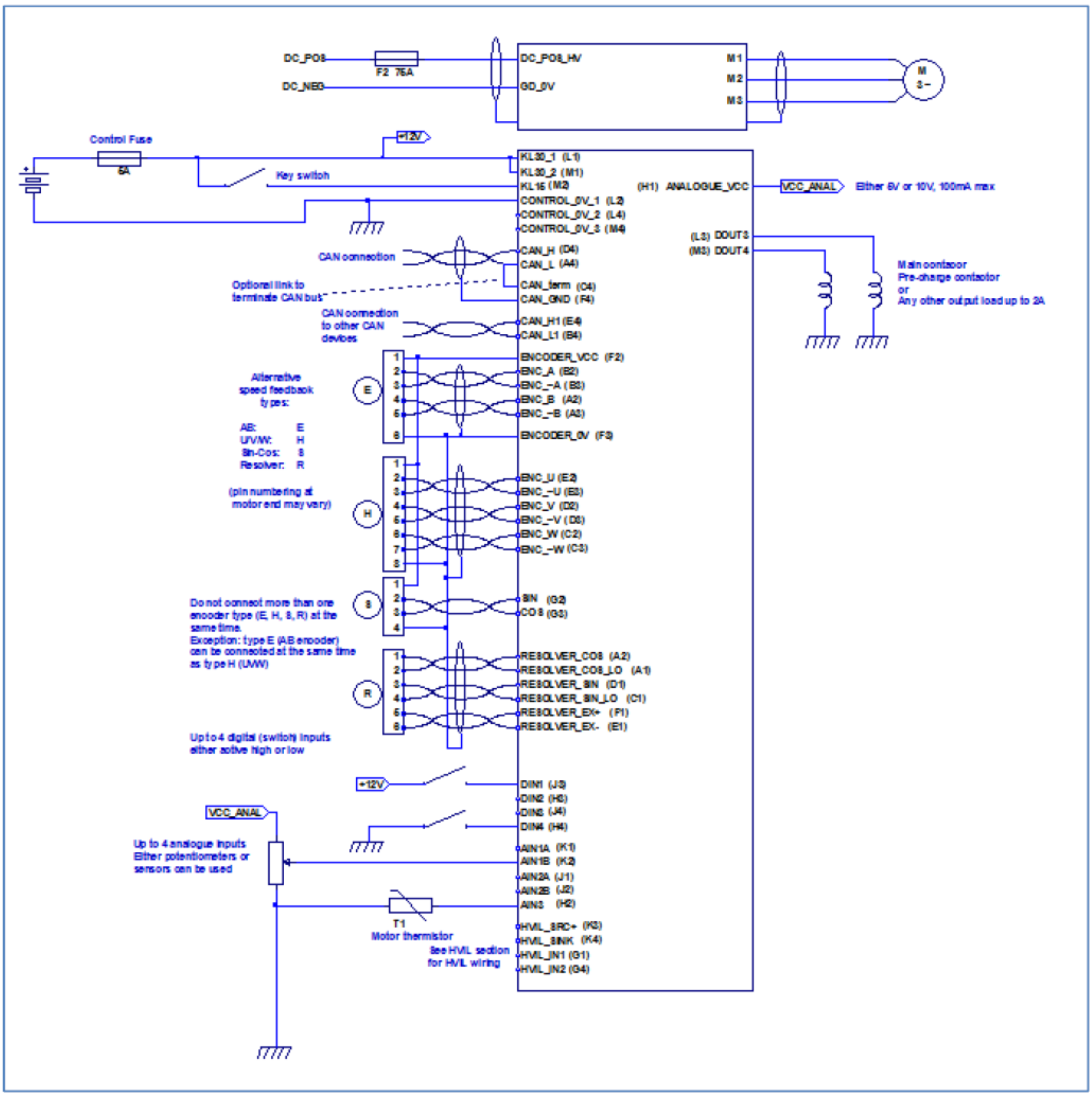


Figure 28 – HVLP Alpha Wiring Diagram

BorgWarner

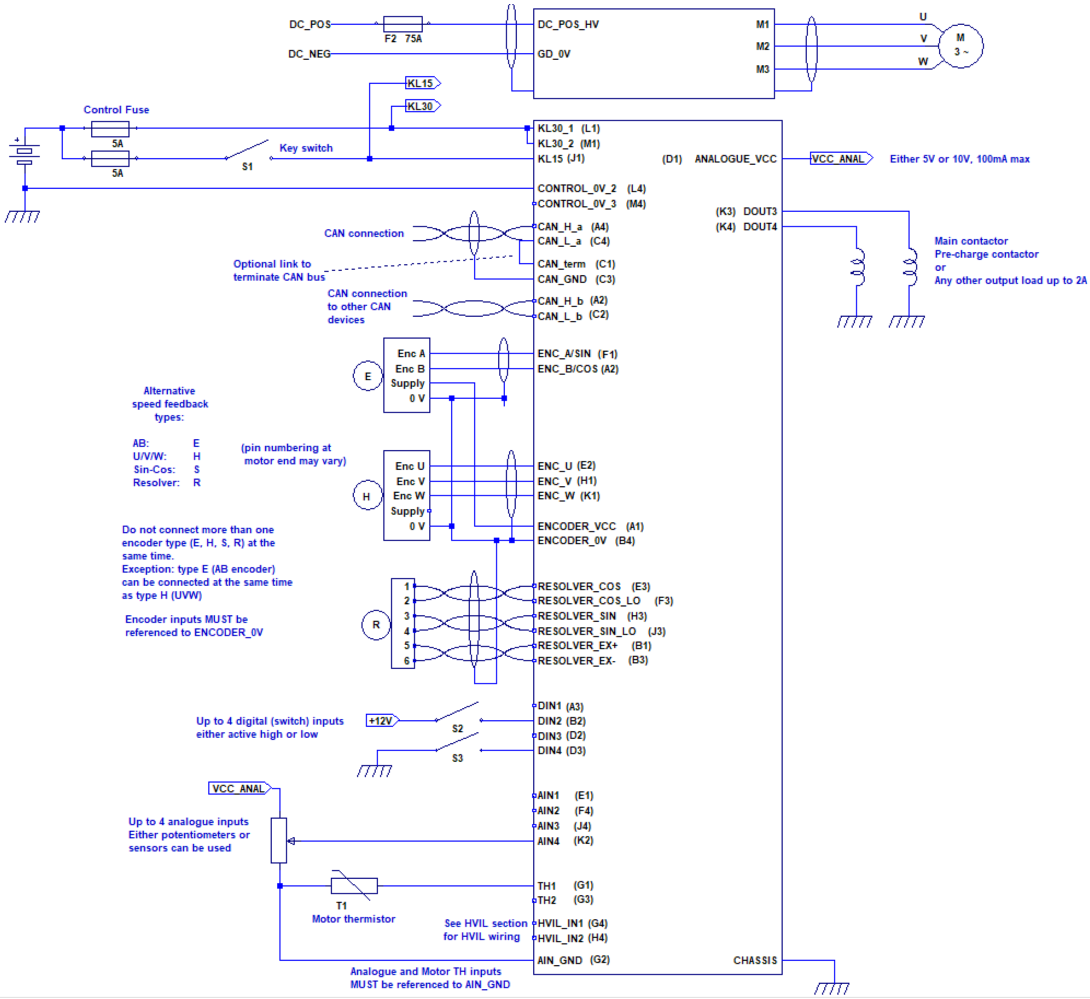


Figure 29 – HVLP Beta Wiring Diagram

6.2 Auxiliary Components (including fuses)

6.2.1 Main Contactor and Pre-charge circuit

The HVLP-10/20 does not offer any internal pre-charge function. Pre-charge must be done externally to the HVLP unit. An external device must be used to isolate the HVLP-10/20 from the vehicle battery. This external device is also responsible for any capacitor pre-charging required to prevent damage to the line contactor tips.

It is recommended that the pre-charge circuit is connected as shown in Figure 30 .The circuit is intended to operate in the following manner:-

- At start-up K1 must be energized, the controller DC bus voltage should be monitored and should have reached 90% of the battery voltage within 5 seconds.
- 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-energized.

At shut-down K1 and K2 may be de-energized simultaneously.

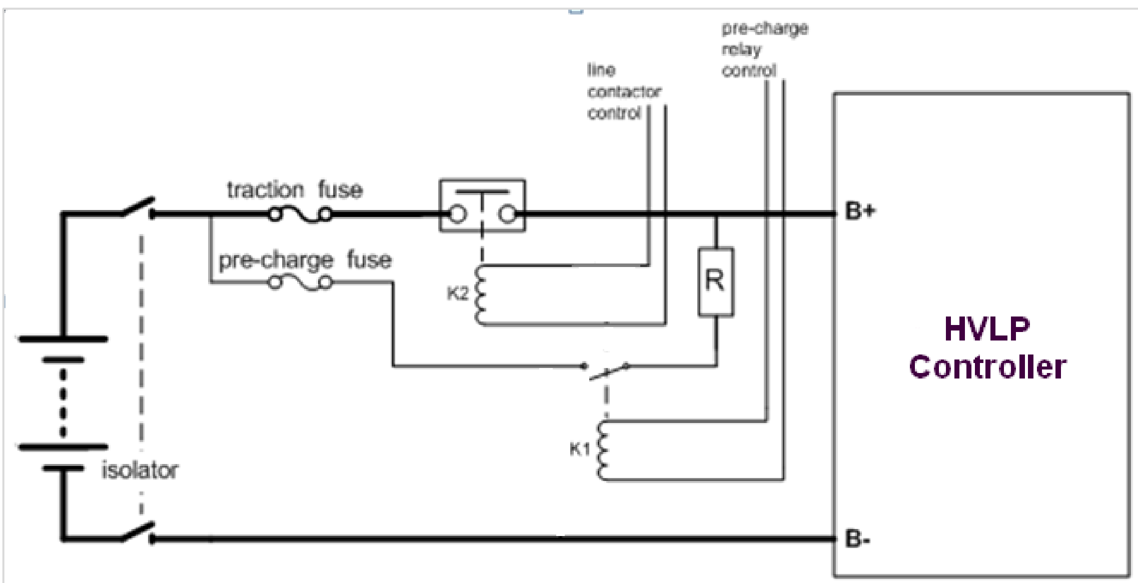


Figure 30 – Line contactor and pre-charge wiring diagram

Components required for the pre-charge circuit are listed in Table 23.

Name	Function	Required specification	Comment
F1	Pre-charge fuse	10A/20A 700V/1000V DC Slow blow preferred	e.g. Cooper Bussman 170M1308 (700V rating) Cooper Bussman 170M4802(1000V rating, 20A)
F2	Main fuse	50A 700V/1000V DC Semiconductor fuse	e.g. Cooper Bussman 170M1314 (700V rating) Cooper Bussman 170M4807(1000V rating)
K1	Pre-charge contactor/relay	Single pole 700V/1000V DC 10A	For example, from Schneider TeSys range
K2	Main line contactor	Single pole 900V DC 50A	Must be interlocked so that K2 can only close if K1 is energized.
R1	Pre-charge resistor	Resistance 220Ω to 1kΩ Pulse voltage 1000V Energy pulse 150J Power 25W	Must be overload protected with thermal cut out and or fuse

Table 23 – Pre-charge Components

Failure to use a capacitor pre-charge circuit may lead to damage to the controller. Note that the DC bus capacitors remain charged at hazardous voltages for several minutes after contactors K1 and K2 are opened and the HVLP powered down. If required a discharge circuit should also be integrated into the system.

Note: 700V fuses suggested above should only be used if the nominal DC bus voltage is 700VDC or less, otherwise 1000V fuses should be used.

6.2.2 Digital Outputs from HVLP-10/20

The digital outputs can provide up to 2A each and can be used for various purposes (e.g. lamps, relays, contactors). But users should be aware that these outputs are powered from KL15 (key-on supply). If the key-switch is turned off the contactors would open immediately even if the motor was turning.

See Figure 31 for a circuit diagram showing the internal components.

The outputs are short circuit proof and thermally protected, but users should be aware that if a flyback diode is connected in parallel with the load inductor coil, the controller will be damaged in the event of reverse battery connection for the logic.

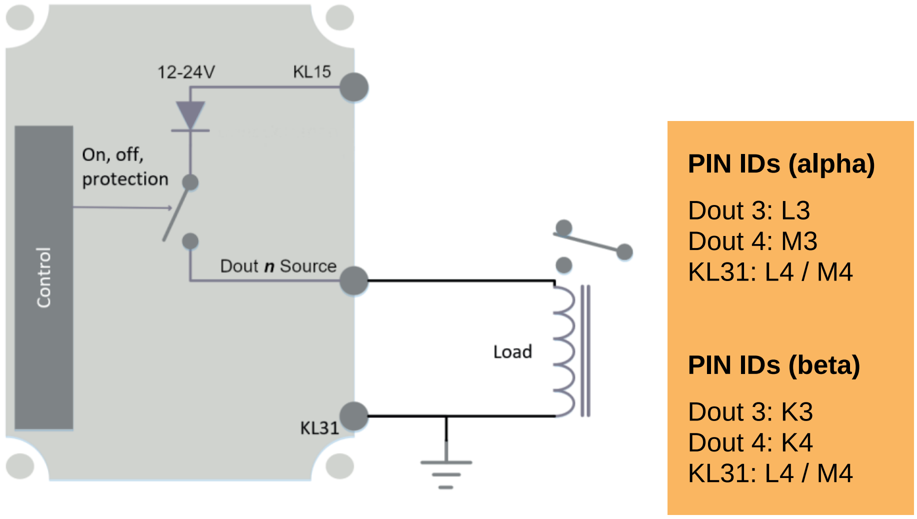


Figure 31 – Digital Output Schematic

Note the following:

- Digital outputs are ON/OFF only (there is no PWM function)
- The load is referenced to Control 0V (logic ground)
- The load must not have (and do not fit) a parallel diode, as this would violate the reverse battery protection

6.2.3 Motor speed sensor (AB encoder)

A 6-wire connection is provided for open-collector quadrature pulse encoder devices. These types of encoder are optimized for accurate speed measurement, required for efficient control of induction motors.

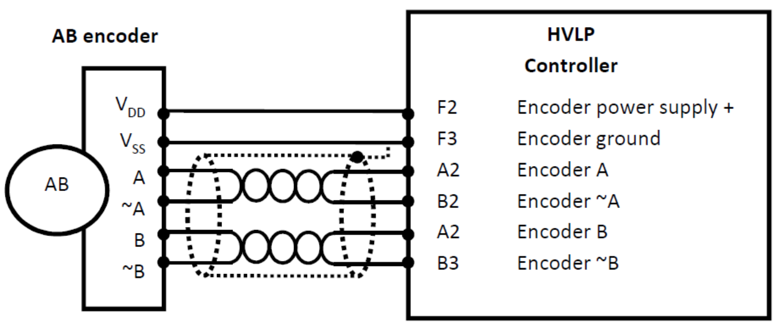


Figure 32 – HVLP Alpha wiring for an AB quadrature speed encoder (encoder pin names may vary).

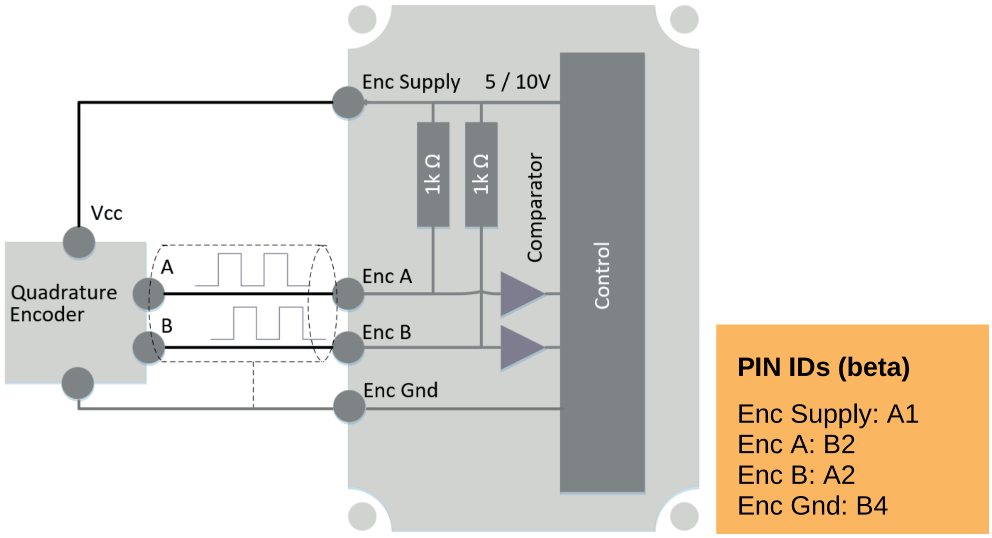


Figure 33 – HVLP Beta wiring for an AB quadrature speed encoder

The number of encoder pulses per revolutions (**n**) and the maximum motor speed (**N**) are related to, and limited by, the maximum frequency of the encoder signal (**f**$_{max}$).

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

with **f**$_{max}$ limited to 200 kHz, and

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

Please refer to I/O Configuration section for information on entering encoder settings.

6.2.4 Motor commutation sensor (UVW, SinCos, Resolver)

Commutation sensors are designed to measure the absolute 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 energize the motor phases appropriately based on the measured position of the magnets on the rotor.

6.2.4.1 UVW Commutation Sensors

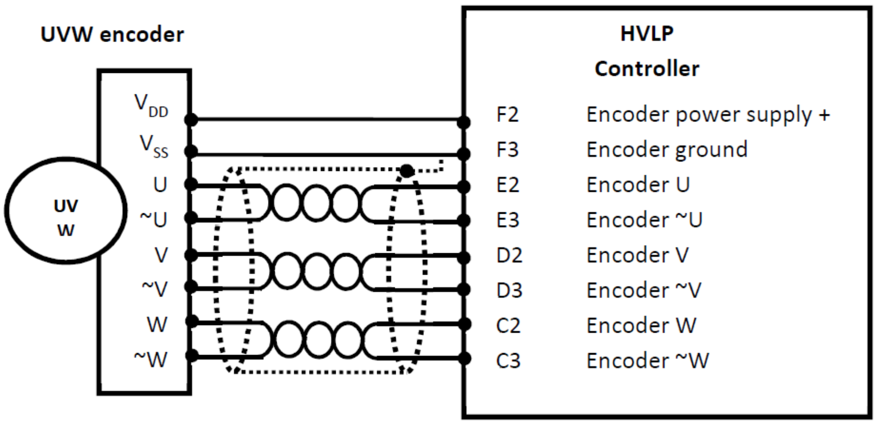


Figure 34 – HVLP Alpha wiring for a UVW commutation sensor (encoder pin names may vary).

In Alpha variant 6 digital inputs are provided for differential UVW encoders, with a 5-10V power supply. The encoder should provide one pulse on each UVW 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. The RS422 inverse of these signals must also be present on the ~U,~V,~W inputs.

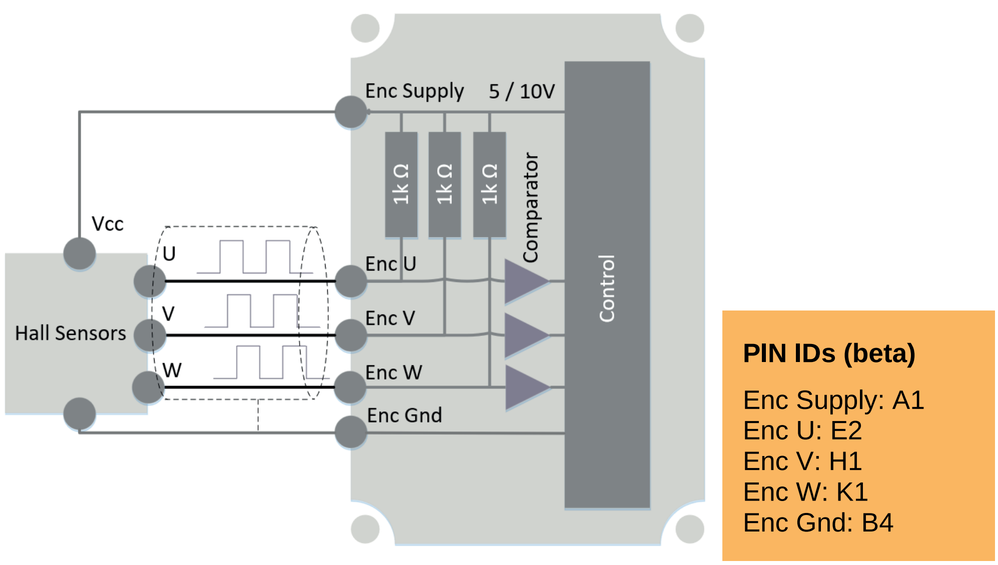


Figure 35 – HVLP Beta wiring for a UVW commutation sensor

In Beta variant 3 digital inputs are provided for UVW encoders, with a 5-10V power supply. The encoder should provide one pulse on each UVW 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 36 shows an example pulse train for the U, V and W inputs.

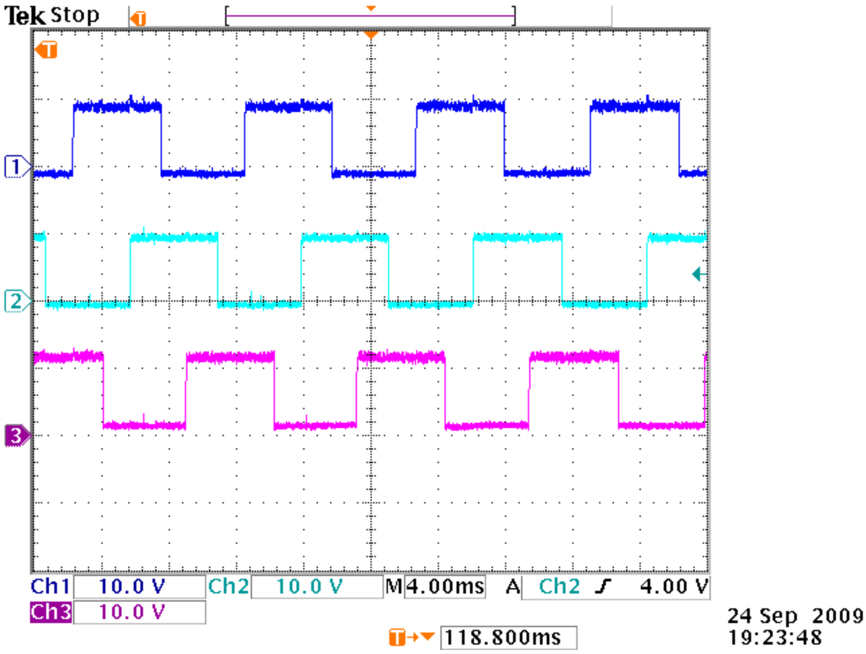


Figure 36 – Example pulse train from a UVW commutation sensor

6.2.4.2 Sin-Cos Commutation Sensor

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

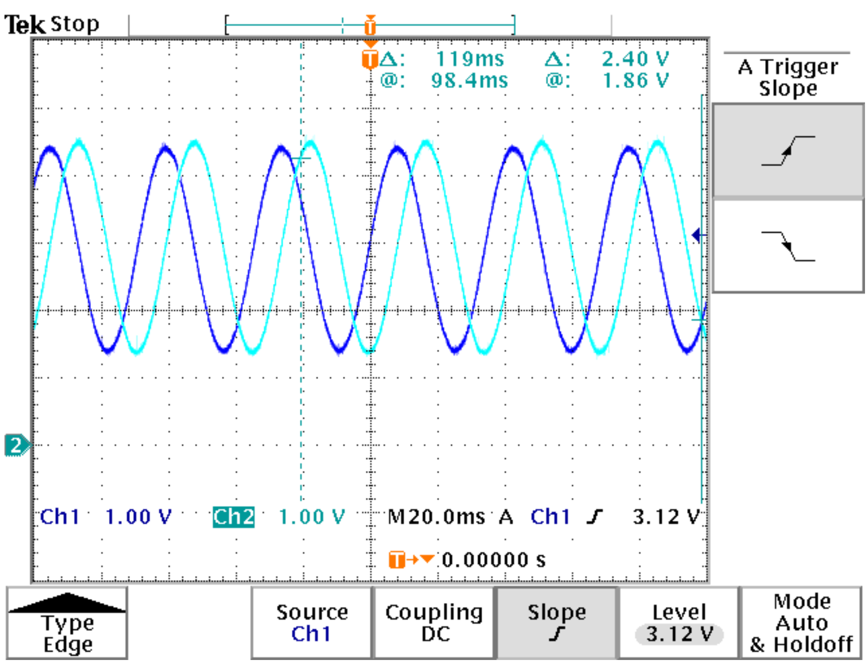
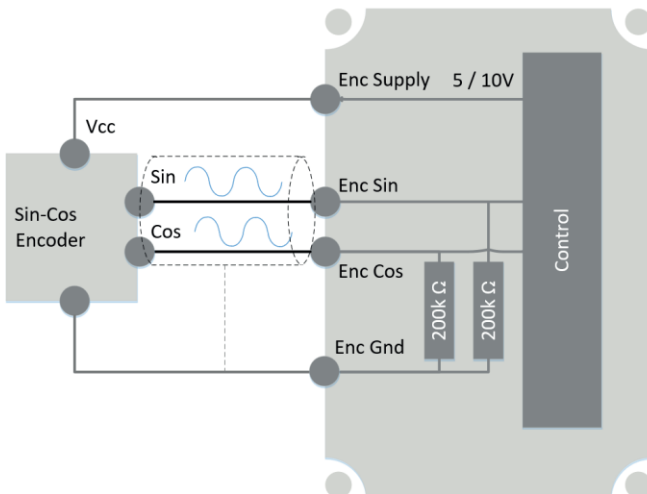


Figure 37 – Example of signals from a sin-cos position sensor

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 (itself an integer only).

For examples:

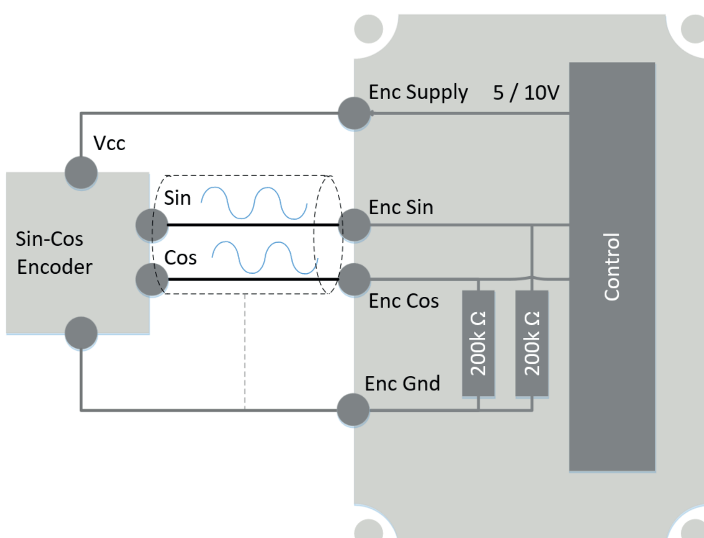
- An encoder that produces 1 wave per rotation can be used with motors with 1 pole pair, 2 pole pairs, 3 pole pairs, etc.
- An encoder that produces 3 waves per rotation can be used with motors with 3 pole pairs, 6 pole pairs, 9 pole pairs, etc.
- An encoder that produces 5 waves per rotation can be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



PIN IDs (alpha)

Enc Supply: F2
Enc Sin: G2
Enc Cos: G3
Enc Gnd: F3

Figure-38 – HVLP Alpha wiring for a sin-cos commutation sensor



PIN IDs (beta)

Enc Supply: A1
Enc Sin: B2
Enc Cos: A2
Enc Gnd: B4

Figure 39 – HVLP Beta 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 Encoder Vcc. This should be done by setting the encoder configuration object dictionary entry at 4630_h.

6.2.4.3 Resolver

The resolver is a position feedback device which requires a sinusoidal excitation (provided by the HVLP-10/20 controller). The feedback consists of two pairs of signals: the resolver Sin pair and the resolver Cos pair (Figure 41). 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) and 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.

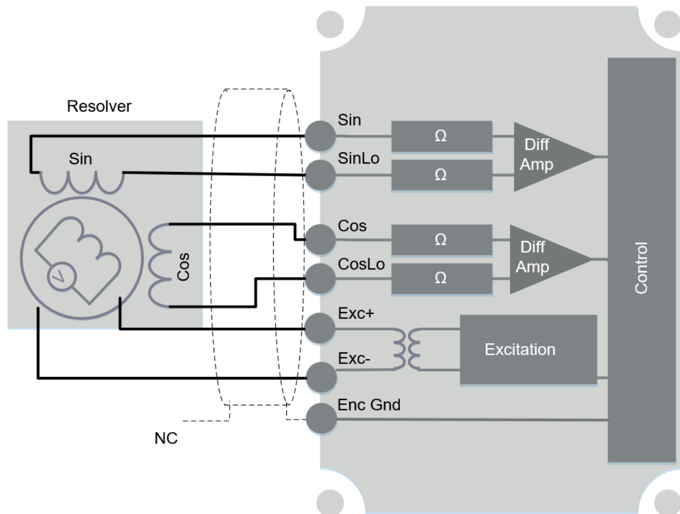
Regarding electrical specification, the following features are required of a resolver to work with the HVLP-10/20:

- Transformer ratio = 0.2 to 0.6
- Excitation frequency = 10kHz
- Excitation voltage = 5Vrms nominal (a resolver specified to 5Vrms or higher will be acceptable)

The controller is able to control motors with multiple pole-pair resolvers (i.e. returning 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 resolver pole pairs.

For example:

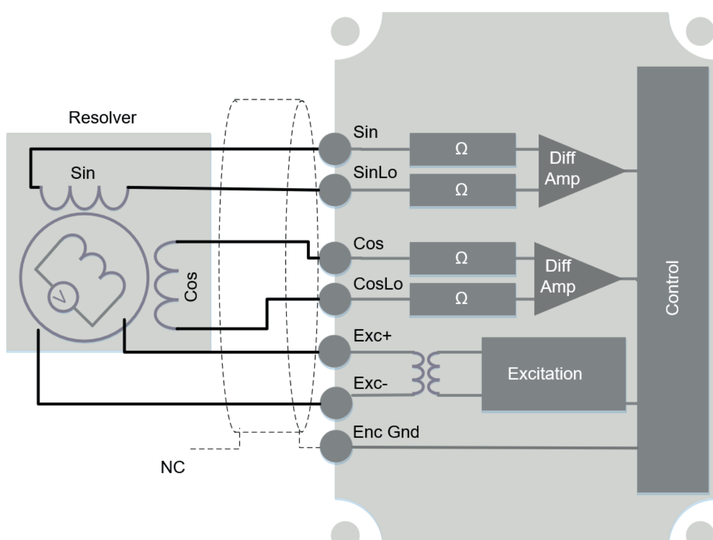
- A single pole pair encoder can be used with motors that have 1 pole pair, 2 pole pairs, 3 pole pairs, etc.
- A 3-pole pair encoder can be used with motors that have 3 pole pairs, 6 pole pairs, 9 pole pairs, etc.
- A 5-pole pair encoder can be used with motors that have 5 pole pairs, 10 pole pairs, 15 pole pairs, etc.



PIN IDs (alpha)

Res Exc+: F1
Res Exc-: E1
Res Sin: D1
Res Sin Lo: C1
Res Cos: B1
Res Cos Lo: A1
Enc Gnd: F3

Figure 40 – HVLP Alpha Sample wiring for a resolver



PIN IDs (beta)

Res Exc+: B1
Res Exc-: B3
Res Sin: H3
Res Sin Lo: J3
Res Cos: E3
Res Cos Lo: F3
Enc Gnd: B4

Figure 41 – HVLP Beta Sample wiring for a resolver

Only connect a single type of encoder to the HVLP-10/20 at any given time.

6.3 Initial power up sequence

Incorrectly wired or configured vehicles may behave in unexpected ways.

6.3.1 Checks prior to power up

Follow this checklist prior to applying power to your system:

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

6.3.2 Checks after power is applied

Apply power and do the following:

- Use BorgWarner DVT (see DVT configuration tool section) or any CANopen configuration tool to complete the configuration process which starts on page Motor characterization.
- Using the drive controls ensure the motor rotates in the expected direction. If they do not, check the motor wiring, encoder wiring and encoder configuration (see I/O configuration).

6.4 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.

6.4.1 Controller discharge profiles

The following oscilloscope plot shows the standard controller discharge curve. This curve only applies if the discharge circuit in Main Contactor and Pre-charge 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. It is essential to check the voltage on the power terminals with a suitable voltmeter before any hand contact is made.

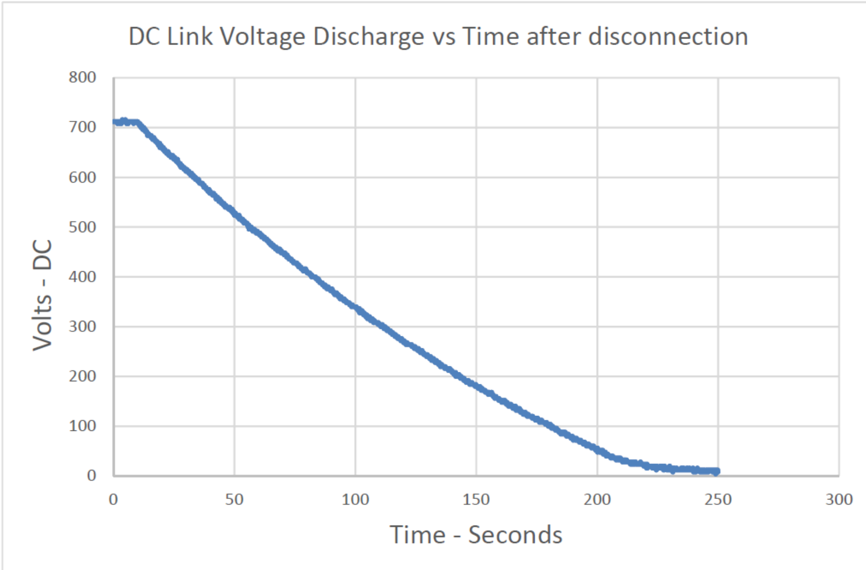


Figure 42 – HVLP Alpha Typical discharge curve for the HVLP-10/20 controller

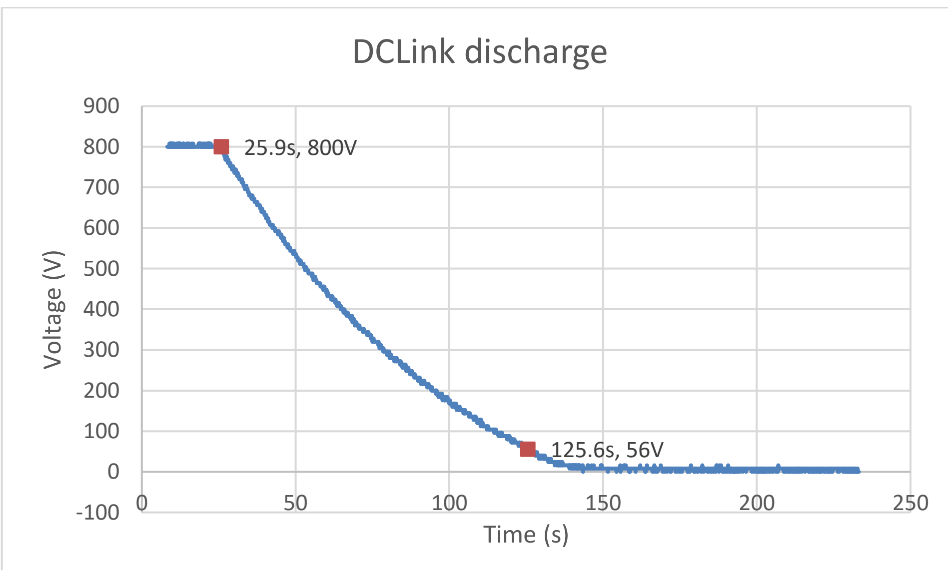


Figure 43 – HVLP Beta Typical discharge curve for the HVLP-10/20 controller

The discharge time to pass from 800V to 60V was 99.7s and the discharge time from 700V to 60V was 91.4s

The unit is labelled with the following signs ("Dangerous voltage") and indicates a "Discharge time" according to the IEC 61800-5-1 standard.

This information is for guidance only, and before any work is carried out on the high voltage connections, it is essential the voltage is checked using a DVM and probes rated for at least 1000V

The maximum specified discharge current is 5mA, typical at 700V DC 1.6mA

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

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.

Chapter 7: Configuration

Chapter 7 - Configuration

7.1 Introduction

This section covers what you need to do to configure HVLP-10/20's software once you have designed and installed your hardware. All of HVLP-10/20'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 (refer to DVT latest user manual)
- CANopen: an introduction to the protocol and its use in BorgWarner 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

7.2 DVT configuration tool

DVT is BorgWarner's proprietary configuration tool. It allows the user to monitor, configure and duplicate the parameters of any BorgWarner CANopen node such as the HVLP-10/20 controller. The information presented here is an overview only. Refer to the separate DVT Manual for more information about DVT and the functions it provides.

7.2.1 DVT functionality

DVT provides the following facilities:

- Configuration of controller IO, CANbus and motor parameters
- Loading DCF configuration file into the BorgWarner 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

7.2.2 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 CAN bus.
- Restore a configuration to a node.

For example, if you want to save the HVLP-10/20 controller configuration, you will need to create a DCF file. To do this, open the DVT Configuration helper by clicking the  icon at the top of the DVT main window.

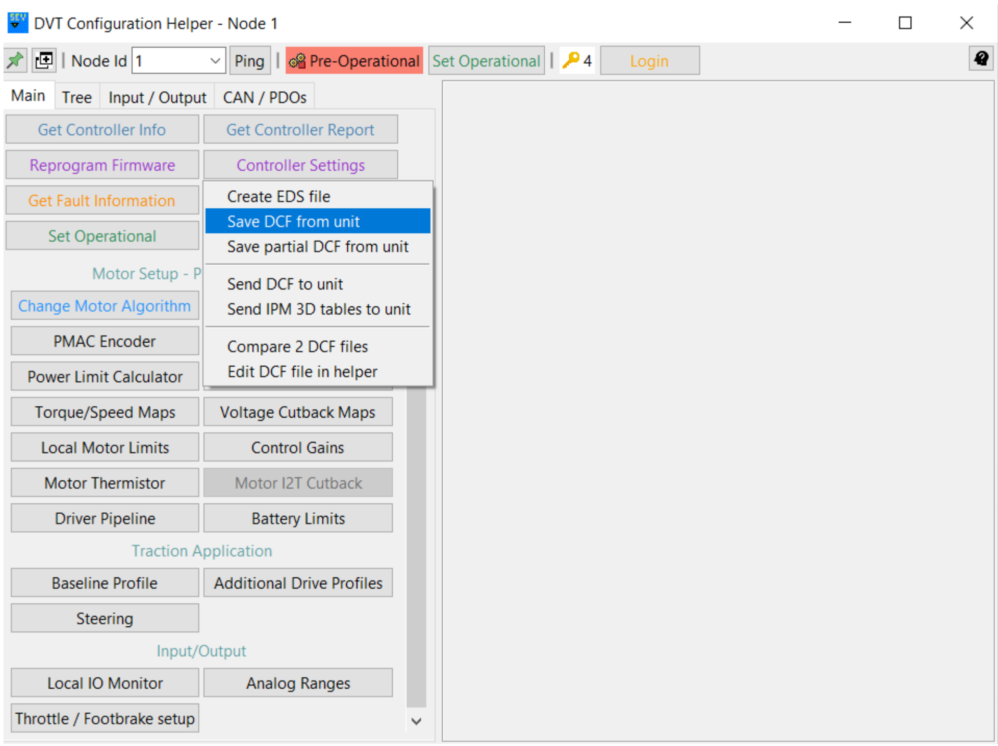


Figure 44 – DVT Helper

7.2.3 Data Logging

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

BorgWarner

7.3 CANopen Configuration

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 HVLP-10/20 controller.

7.3.1 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.

7.3.2 Object Dictionary

The HVLP-10/20 controller uses CANopen principally for configuration purposes. All settings and configuration can be accessed via the controller’s object dictionary, and parameters can be monitored and adjusted using CANopen’s SDO protocol. This protocol is also implemented in DVT, allowing it to be used as the primary device configuration tool.

Any device connected to the CANopen network is entirely described by its Object Dictionary. The object dictionary defines the interface to a device. Within the Object Dictionary, all parameters are assigned a unique index and sub-index. Thus, all parameters can be uniquely addressed by this pair of numbers.

There are two important text files associated with the Object Dictionary. These are:

7.3.2.1 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 BorgWarner’s DVT to describe the structure of a node’s Object Dictionary. An EDS for each HVLP-10/20 model and software version, is automatically generated using BorgWarner’s DVT tool. The EDS file format is described in the DSP306 – Electronic Data Sheet Specification.

Each Object Dictionary matches a particular HVLP-10/20 software revision, and its structure is hard coded into the controller software.

7.3.2.2 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 HVLP node’s Object Dictionary.
- Save the current configuration of a HVLP node’s Object Dictionary for future use.

7.3.3 Network Configuration

7.3.3.1 General multi-node configuration

Use the following procedure to setup the HVLP-10/20 controller on the network:

1. Set node ID and baud rate in 5900h 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 SYNC producer, or to 0x00000080 for the SYNC consumers. 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 VCU. On the SYNC producer, set the SYNC rate in 1006_h.
3. Set the EMCY message COB-ID to either 0x00000000 or 0x80 + node ID in 1014_h. Setting to 0x00000000 will automatically calculate the EMCY COBID from the node ID.

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 CAN bus communication from any one node must cause a heartbeat fault to occur.

6. Where supported, hardware CAN bus fault detection should be enabled at 5901_h to ensure CAN bus fault detection is always enabled.
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. Configure RPDOs (1400_h to $17FF_h$) and TPDOs (1800_h to $1BFF_h$) appropriately for the system.
9. Configure the RPDO timeout function if required. See section PDO) for more information.
10. Set up the VCU to comply with the required H-protocol and I-protocol messages for motor control and I/O control.

7.3.3.2 3rd Party CANopen Devices

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

HVLP knows how to react to EMCYs (faults) from BorgWarner slaves and can take appropriate action. HVLP 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.

7.3.4 PDOs

The controller supports 2 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 non-critical data between CAN bus nodes.

H-protocol and I-protocol should be used to communicate motor and I/O data.

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 24.

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 24 – Objects associated with mapping

HVLP-10/20 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 heartbeat protocol (see section Network Configuration) is assumed to be used.

7.4 H-Protocol

Although device configuration takes place using standard CANopen messages which are used to access the device's Object Dictionary, the proprietary H-Protocol is used to communicate motor control and status information over a CAN network.

H-Protocol is an enhanced motor control protocol. It is designed specifically for use with slave applications that require fast response times and a fine degree of control, but is equally suited to any electronic motor control application.

H-Protocol allows a VCU to control:

- Inverter bridge state
- Motor output torque
- Motor speed limits in both the forward and reverse directions
- DC current limits for both drive and regeneration
- Overall torque limits for both driving and braking torques

H-Protocol allows a VCU to monitor:

- Motor speed and actual output torque
- Motor, inverter, and internal component temperatures
- DC voltages and currents
- Inverter bridge state
- Fault codes

7.4.1 J1939 Compatibility

The network layer used by H-Protocol is intended to be compatible with J1939 type networks. Whilst non-standard PGNs are used to represent the data, the J1939 concepts for routing data and providing peer-to-peer communication between a VCU and motor controller are used heavily by H-Protocol.

The PGNs used by H-Protocol can be configured by adjusting the parameters in the object dictionary at index 3F00h. Any PDU1 format PGNs can be used by H-Protocol. However, the following default configuration is recommended wherever possible:

Name	Description	PGN (dec)	PGN (hex)
HC1	Torque demand message 1	69632	0x11000
HC2	Torque demand message 2	69888	0x11100
HC3	Battery demands	70144	0x11200
HS1	Torque feedback	71680	0x11800
HS2	Inverter status feedback	71936	0x11900
HS3	Temperature feedback	72192	0x11a00
HS4	Fault Information	72448	0x11b00
HS5	Encoder Information	72704	0x11c00
HD1	Debug Currents	75776	0x12800
HD2	Debug Voltages	76032	0x12900
HD3	Debug Temperatures A	76288	0x12a00
HD4	Debug Temperatures B	76544	0x12b00

HD5	Debug Control PMAC	76800	0x12c00
HD6	Debug Control FV	77056	0x12d00

Table 25 – H-protocol PGN

Further details regarding the layout of signals within these messages is available from BorgWarner on request.

If a VCU is not available to generate motor control demands in H-Protocol format, TracApp can be used instead.

H-Protocol includes an integrated timeout feature. If the motor controller does not receive H-Protocol commands for a specified timeout period, the motor will automatically output zero torque, and will also attempt to report this condition to the controlling device.

Sequence Counter:

Object reference 0x4655,2 Set this to 0xE38E to disable the message validation checks – this is needed for controlling via DVT or CANalyzer. Setting this disables the check on the message counter and checksum flags. To re-enable set any other value (typically 0).

The message validation checks must not be left disabled after configuration is completed. Failure to observe this requirement may affect safe operation of the controller.

7.5 I-Protocol

I-Protocol works alongside H-Protocol to allow monitoring and provide control of digital and analogue input and output devices.

I-Protocol allows a VCU to control:

- Digital outputs
- Analogue outputs (contactor drives)

I-Protocol allows a VCU to monitor:

- State of digital inputs
- Analogue input voltages
- Fault codes

7.5.1 J1939 Compatibility

Like H-Protocol, I-Protocol is intended to be compatible with J1939 and communicates using PDU1 type PGNs. The PGNs used by the IO controller can be configured in the Object Dictionary at index 3F01h. However, the default PGNs listed below should be used if possible:

Name	Description	PGN (dec)	PGN (hex)
UO1	User Analogue (digital) Output Control 1-4	81920	0x14000
UO2	User Analogue (digital) Output Control 5-8	82176	0x14100
UF1	User I/O Fault Status and Digital Inputs	83968	0x14800
UI1	User Analogue Inputs 1-4	84224	0x14900
UI2	User Analogue Inputs 5-8	84480	0x14a00
UI3	User Analogue Inputs 9-12	84736	0x14b00
UI4	User Analogue Inputs 13-16	84992	0x14c00

Table 26 – I-protocol PGN

Further details regarding the layout of signals within these messages is available from BorgWarner on request.

7.6 Configuration process overview

Electric vehicles can be dangerous. All testing, fault-finding and adjustment should be carried out by competent personnel.

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. figuration requirements

7.6.1 Access authorization

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

To login write your 32-bit password to object 5000_h sub-index 4. The access level can be read back from sub-index 1. The passwords for access levels 1 to 4 are fully configurable by the customer in 5000_h sub-indices 5-8 so they can be made unique. Log in at access level 4 is required to change the passwords. Once the passwords have been changed, they can be stored in the DVT tool so that controller configuration can still be altered with DVT.

CAUTION: Make a note of any changed passwords. Resetting forgotten passwords can only be performed by BorgWarner.

7.6.2 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 HVLP-10/20 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.

The NMT state can be determined by monitoring the heartbeats or by reading 5110_h. 0x05 = operational and 0x7F = pre-operational.

7.7 Motor characterization and encoder

Ensure you have completed the CANopen network setup process.

7.7.1 Determining and configuring motor parameters

Key motor parameters for permanent magnet ac and induction motor are adjustable in 0x4641.

Contact BorgWarner or Authorized Distributor for more information on how to set up the HVLP-10/20 controller for supported motor types.

An application note is available for V/F induction motor configuration

7.7.2 Encoder configuration

It is important that the encoder parameters are entered correctly. Incorrect encoder configuration can lead to dangerous motor operation

An application note is available for HVLP encoder configuration.

7.7.2.1 General encoder settings

Encoder selection and settings applicable to all encoder types are contained in 4630_h and 4631_h.

HVLP supports four encoder types:

- Resolver absolute position sensor
- Sine-Cosine absolute position sensor
- UVW absolute position sensor
- AB incremental speed encoder

AB is not suitable for synchronous motors (e.g. permanent magnet AC).

- For sensors requiring a DC power supply (Sine-Cosine, UVW, AB), set the required sensor supply voltage (from 5V to 10V) in 4630_h.
- If the encoder sequence is incorrect with respect to the motor, then this inversion can be performed within 4631_h, without rewiring the motor.
- Sensor latency compensation and advanced noise filtering is applied to all sensor types. Please contact BorgWarner or refer to the HVLP encoder application note for recommended settings for these items.
- If using a PMAC motor, the absolute offset of the encoder is configured in 4630_h, sub 4. A range of +/-180° may be input. Units are in electrical degrees.
- The software has provision for an approximate auto-detection of the encoder offset using a low-speed rotation test, provided the motor is unloaded. Please contact BorgWarner or refer to the HVLP encoder application note for information on this feature.

7.7.2.2 Resolver configuration

Please refer to Resolver section for electrical information on the resolver subsystem.

All resolver specific settings are located in 4632_h.

- The controller can support multi pole-pair resolvers. Please see section Motor commutation sensor for information on pole pair values other than 1.

- The controller supports a range of resolver gains by manipulating the magnitude of the excitation waveform. The phase of the resolver must also be compensated for, to achieve optimum performance. Resolver gain and phase settings can be auto detected by the HVLP. Please contact BorgWarner or refer to the HVLP encoder application note for information on tuning resolver magnitude and gain settings.

7.7.2.3 Sin/Cos configuration

Please refer to section Motor commutation sensor for electrical information on the sin/cos subsystem

Sin/cos specific settings are located in 4633_h.

- The controller can support sin/cos encoders with multiple waves-per-revolution. Please see section Motor commutation sensor for information on waves-per-revolution values other than 1
- The minimum and maximum voltage levels of the sin/cos encoder must be entered in 4633.
- To assist in configuration, the controller provides real-time feedback of the minimum and maximum sin/cos voltage levels. A rotating motor is required to determine these thresholds.
- To account for any sin/cos sensor latency, please ensure the correct latency is set in the general encoder settings (4631_h). Please contact BorgWarner or refer to the HVLP encoder application note for recommended latency settings for specific sin/cos sensors.

7.7.2.4 UVW configuration

Please refer to section Motor commutation sensor for electrical information on the UVW subsystem. Please note that in HVLP Alpha the UVW is a differential-input system requiring a differential signal pair for each UVW input while in in HVLP Beta variant UVW is a single ended-input system. The 5V or 10V supply is configurable.

For a PMAC motor, a full 360º sequence of UVW pulses must be present for each electrical cycle of the motor.

UVW specific items are located in 4634_h.

- If the UVW inputs are inverted (active-low) then this inversion can be accounted for in the UVW settings. Alternatively, the encoder sequence can be inverted in the general encoder settings (4631h).
- If significant latency is present, this can be accounted for in the general encoder settings (4631h). Please contact BorgWarner or refer to the HVLP encoder application note for recommended latency settings.

7.7.2.5 AB configuration

Please refer to section Motor speed sensor (AB encoder) for electrical information on the AB subsystem. Please note that in the HVLP Alpha variant AB is a differential-input system requiring a differential signal pair for each AB input while in the HVLP Beta variant AB is a single ended-input system. The supply voltage of 5V or 10V is configurable.

Please note, AB is not suitable for PMAC motors, where absolute position is required. AB specific items are located in 4635_h.

- The pulses per revolution must be set to match the encoder.
- If the AB inputs are inverted (active-low) then this inversion can be accounted for in the AB settings. Alternatively, the encoder sequence can be inverted in the general encoder settings (4631h).

7.8 Torque conditioner

The torque conditioner is used to modify the torque demand received over CAN or from local master functionality (Pump Application) to apply inverter and motor thermal protections, DC link voltage and current cutbacks and to follow the requested motor speed limits.

Contact BorgWarner or Authorized Distributor for more information on how to set up the HVLP-10/20 controller torque conditioner.

An application note is available for HVLP torque conditioner

7.8.1 Speed Limit Tuning

The speed limit is controlled using PI loops, which can be configured in the Object Dictionary at index 4651h. The following parameters can be configured:

- Standard proportional and integral gains (4651h, 1+2). Used to configure the loops during normal operation.
- Low speed proportional and integral gains (4651h, 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 avoid oscillations as the vehicle comes to a stop.
- Roll back integral gain (4651h, 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 (4651h, 6). This is used to apply compensatory torque to damped oscillations induced from the vehicle drive train. Not used in torque mode.
- Integral initialization factor (4651h, 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.
- Speed filter pole (4651h, 8). Used to filter speed used by speed limit loop.
- Speed pre-limit threshold (4651h, 9). Speed limit algorithm will start cutting back torque when speed is within this threshold of the maximum.

7.9 I/O configuration

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

The individual characteristics of the I/O in your application need to be setup. Setup each hardware I/O object, including wire-off protection.

I/O control is managed using the I-Protocol. Refer to the I-Protocol and J1939 VehApp Mapping application notes for more information.

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.

7.9.1 Digital inputs

The state of the digital inputs can be monitored using I-Protocol.

Digital inputs are interpreted as both active high and active low. The value returned via the I-Protocol is individually configurable.

Digital input statuses are constantly monitored and interpreted and are output using the I-Protocol as “active”, “inactive” or “error”.

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.

The digital inputs thresholds vary according to the KL15 supply voltage:

4680h set Active high

Input considered active when rises above 0.775 * V_{KL15}

Input considered inactive when falls below 0.759 * V_{KL15}

4680h set Active Low

Input considered active when falls below 0.242 * V_{KL15}

Input considered inactive when rises above 0.259 * V_{KL15}

7.9.2 Analogue inputs

The analogue input voltages are read from I-Protocol messages, values are 12bit fixed point values with a resolution of 1/256 V/bit (4:8 bit format), with 0xfff used to indicate that a channel is not used.

The following table summarizes the analogue inputs and any special features:

Name	Pin	Usage
Analogue Input 1a	K1	Input from external voltage source or 3-wire pot wiper. Use pin H1 as supply for 3-wire pot.
Analogue Input 1b	K2	
Analogue Input 2a	J1	
Analogue Input 2b	J2	
Analogue Input 3 (Motor Thermistor)	H2	Use for motor thermistor input or 2-wire pot input. Has internal supply.

Table 27 – HVLP Alpha Analogue inputs

Name	Pin	Usage
Analogue Input 1	E1	Input from external voltage source or 3-wire pot wiper. Use pin H1 as supply for 3-wire pot.
Analogue Input 2	F4	
Analogue Input 3	J4	
Analogue Input 4	K2	
Motor Thermistor Input 1	G1	Use for motor thermistor input or 2-wire pot input. Has internal supply.
Motor Thermistor Input 2	G3	

Table 28 – HVLP Beta Analogue inputs

There is a variable analogue supply at pin H1 (Alpha) and pin D1 (Beta). Analogue supplies may also be controlled using the I-Protocol. Refer to the I-Protocol documentation for more information.

7.9.2.1 Wire-off detection

Enable wire-off detection at 46C0h to 46C2h. For each input specify the allowable range of input voltages. To disable, set the ranges to maximum.

7.9.2.2 Motor thermistor input

You can connect a thermistor sensor to the Motor thermistor input.

Type	Specification
PTC Silistor	Philips KTY83, PT1000 etc.

Table 29 – Motor thermistor input

To setup go to object 4620_h:

- Configure as none, thermistor or CAN based thermistor

- Program the resistance / temperature profile in $461F_h$. This is an 8-point table which allows a programmable thermistor table to be configured.
- The lower and upper bounds of the table should be set beyond the minimum and maximum temperature that could be experienced (typically -40°C, +200°C) This is to allow the sensor open/short detection to function.
- For CAN based thermistors, the temperature can be loaded into object 4600_h sub 16 using an RPDO.
- After configuration, test the sensor with short circuit and open circuit to ensure a fault is detected and reported.

Read the measured motor temperature (PTC) or switch operation at object 4600_h.

An application note is available for HVLP motor thermistor configuration.

7.9.3 Digital (contactor) outputs

There are 2 digital outputs which can be used to control loads such as contactors, horns, lights, etc.

7.9.3.1 Error control

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

In a CAN network, the slave node on which the contactor output is different to the VCU node which calculates the output value. If the CAN bus fails, the VCU 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 CAN bus 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.

Some examples of typical configurations may be:

- Electro-mechanical brake on slave node. If CAN bus 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 CAN bus communication is lost, it may be desirable to leave the power steer output in its previous state. In this case, disable error control in $6C43_h$.
- CAN bus communication error lamp on slave node. If CAN bus 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 CAN bus failure.

7.10 Vehicle Master Functions

7.10.1 Pump configuration

The controller can use a mixture of switch and analogue 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.

NOTE: Pump motors always run in speed mode.

7.10.1.1 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 the 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.

7.10.1.2 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 $2A26_h$.

7.10.1.3 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. The pump throttles must be mapped to analogue inputs.

7.10.1.4 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.

7.10.1.5 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 $2A31_h$

7.10.2 Power steer configuration

7.10.2.1 General

Power steering can be provided using:

- Contactor. Map the power steer contactor drive object to an analogue 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

CAUTION: 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.

7.10.2.2 Variable Assist Power Steering

HVLP 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.

7.11 Vehicle features and functions

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

7.11.1 Line contactor

A line contactor can be mapped to a digital output on the HVLP. Its purpose is to isolate the controller and motor from the battery during power down or when a serious fault occurs. It is normally closed whenever the system is under power. However, it can be configured to open after the vehicle has been stationary for a period of time via object 2820h.

Some form of capacitor pre-charge must be employed before the line contactor closes. Otherwise, very high inrush current will weld the contactor tips. The controller may be damaged, as well.

NOTE: It is recommended that the capacitors are charged to at least 90% of battery voltage before closing the line contactor. This may be done by a pre-charge relay (driven by the HVLP) and an external resistor.

The HVLP can be configured to control a pre-charge relay. If configured, it will close at power up and charge the capacitor bank through a resistor. If no faults are detected and the minimum pre-charge voltage is reached, the main line contactor will close. The minimum capacitor voltage required for the line contactor to close is set in object 5821_h.

7.11.2 External LED

This mirrors the operation of the controller's internal diagnostic LED. The external LED can be mapped to a digital output to drive a lamp on the vehicle dashboard.

7.11.3 Alarm buzzer

The alarm buzzer can be mapped to a digital 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.

7.11.4 Motor over-temperature protection

The controller protects motors from over-temperature. It calculates the motor temperature via an analogue input (for a thermistor) or a digital input (for an over-temperature switch).

Additional protection is provided for thermistor wire-off conditions. If the temperature sensor input measures a completely short circuit or open circuit signal, then the output torque will begin to reduce gradually over time. A recovery rate can also be specified should the signal become valid again. This means that wire-off situations, should they occur during drive, do not result in an instant loss of torque. Both the torque ramp down and recovery rates can be configured using object 4620 h.

7.11.5 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 4624h. 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.

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

7.11.6 Battery protection

The nominal battery voltage must be set at 2C00h.

7.11.6.1 Over voltage

Battery over voltage usually occurs during regenerative braking.

To provide protection set values for these parameters at 2C01h:

- 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 cut-outs out. A fault is set if the voltage exceeds the cut-out voltage.

7.11.6.2 Under voltage

To prevent excessive battery discharge, set values for these parameters at 2C02h:

- 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 cut-outs 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).

7.11.6.3 Battery Discharge Indicator (BDI)

CAUTION: When not in use ensure the BDI function is disabled by setting the Cell Count (in 2C30h, 6) to 0.

Monitor battery voltage using HVLP'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.

NOTE: 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 2C30h 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.

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

An additional table exists at index 2C31 $_h$ which allows an initial BDI value to be specified at start up based on the measured battery voltage. At start up, the measured battery voltage is taken, and the corresponding BDI percentage remaining value is then used as the starting point for the BDI. After this, the BDI remaining value operates in the standard way. Note, this function is only available if the corresponding bit is set in object 2C30$_h$ sub 1.

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

7.11.7 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.

Object 2870$_h$ controls how the battery current limit is calculated. Sub-index 1 of this object can be set to one of the following values to specify how the current limit behaves:

Value	Mode
0x00	Master control of battery current limit disabled. To completely disable battery current limit, object 4623$_h$ sub index 3 must also be set to 0x0000.
0x01	Battery current limit set by object 4623$_h$ sub index 2 and 3.
0x02	Battery current limit controlled by compatible BMS
0x03	Battery current limit set by object 4623$_h$ sub index 2 and 3, but the drive current limit is multiplied down by factors set in sub index 4 and 5 when driveability profiles are activated
0x04	Battery current limit is calculated to maintain a power limit as set in sub index 6 and 7.

Table 30 – Battery current limit

Object 2871$_h$ provides a means to have TracApp cut back the torque demand in situations where the battery current limit is reduced. This is useful for configurations where an external BMS can cut back the current limits to low levels. Effectively, it prevents TracApp requesting torque that cannot be achieved.

Object 4623_h shows the current limits that are in effect. Sub index 3 of this object allows you to specify the cutback aggressiveness and a measurement correction factor. Setting this to zero. Battery current flow can be monitored at object 5100_h.

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

7.11.8 Displays

HVLP 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 BorgWarner's proprietary CAN protocol. To use set the CAN baud rate to 100kHz at 5900_h, enable SmartView and select hours counter and/or real speed at $2E00_h$.

Chapter 8: Monitoring HVLP
10/20

Chapter 8 - Monitoring HVLP-10/20

8.1 Reading status variables

All status information is contained either in the HVLP-10/20's Object Dictionary or transmitted using either H-Protocol or I-Protocol messages. Most service information can be accessed using SDOs. Some can be mapped to PDOs for continuous transmission to remote nodes such as displays and logging devices.

8.1.1 Motor Data

The following motor data is available on H-protocol:

- Motor torque, speed, battery current
- Available drive and brake torque
- Motor temperature
- Motor control and status words

The following motor data is also available on H-protocol debug messages

- Motor slip frequency, currents and voltages
- Additional motor debug information

8.1.2 Customer Input Data

The following customer input data is available on I-protocol:

- Digital input states
- Analogue input voltages

8.1.3 Device Data

The following device data is available on H-protocol:

- Device temperature
- Power frame (DC link) voltage
- Highest priority fault

8.1.4 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.

8.1.5 Supply monitoring

The controller measures the following supply voltages:

- KL15 and KL30 voltages; measured at KL15 and KL30 inputs and read at 5100_h.
- Capacitor voltage; measured at the B+ terminal. Read at 5100_h and also available on H-protocol.

8.1.6 Hours counters

The controller supports many different hours counters for various functions. Some counters run on all units and some only run on the HVLP-10/20 configured as the vehicle master.

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

The hours counters are:

- KL15 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).

8.2 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.

8.2.1 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 $41X2_h$.

8.2.2 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 HVLP-10/20 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

8.2.3 Operational monitoring

At objects 4300_h and 4301_h, HVLP-10/20 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 BorgWarner engineers. The Customer copy is normally recorded and reset each time the vehicle is serviced. The BorgWarner copy records data over the controller’s entire working life.

8.3 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 as shown in **Table 31**.

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		

Table 31 – Abort Reason Codes

8.4 Faults and warnings

8.4.1 Introduction

In the event of a fault HVLP-10/20 takes the following action:

1. Takes action appropriate to the fault severity. This can be either derating of motor power or speed or shutdown of the power frame.
2. Sends out an EMCY message on the CAN bus and updates the highest priority fault ID in the H-protocol.
3. Logs the fault for later retrieval.

8.4.2 Fault identification

You can identify a fault as follows:

- Pick up the EMCY on the CAN bus and read the fault condition using configuration software
- Interrogate the fault on the node directly using DVT or other configuration software.

8.4.3 Fault list

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

- 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.
- 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.

8.5 Upgrading the controller software

It is possible to field update the firmware of the HVLP-10/20 controller, typically using BorgWarner's DVT configuration tool. However, in most cases this is not necessary as the controller will already have the latest firmware installed.

Please contact BorgWarner or Authorized Distributors for assistance with this process. Also refer to the DVT Manual.

Chapter 9: HVLP Alpha and Beta

Chapter 9 - HVLP Alpha and Beta

9.1 Alpha vs Beta

Please note that HVLP alpha is subject to a “Conditions of Use” document, which is included in the packaging with every unit. Please read this carefully and ensure you agree with all the conditions before using the product. Here are the key points from this document:

- The alpha version of the HVLP inverter is pre-series production and not recommended to be used in vehicle homologation
- The alpha version is not RoHS compliant
- The software for the alpha variant has not been through the formal release process

9.1.1 DC Link Capacitors

While the HVLP-Alpha version has electrolytic capacitors in series and parallel formation with 450µF equivalent capacitive value. The HVLP-Beta version is equipped with improved performance film capacitors in parallel formation with equivalent capacitive value of 120µF.

9.1.2 HVIL Hardware

The Beta variant does not generate HVIL excitation but is capable of monitoring a HVIL loop. As HVLP is intended to drive auxiliary systems it is typical that there will already be a HVIL excitation generator on the vehicle.

9.1.3 Improvements in HVLP-Beta

1. The logic supply storage capacitor was increased in value, to allow the unit to operate during 10ms power outage of the KL30 supply
2. An additional motor thermistor input was added, so 2 external thermistors can be used with HVLP-Beta
3. The two analogue supply outputs were redesigned to improve stability
4. The off-state current (with KL15 low) was reduced to below 1mA for HVLP Beta
5. HVLP Beta is manufactured using lead-free soldering so is RoHS complaint with exemptions 6c, 7c-I, 7a.

9.1.4 Firmware

Different firmware (.dldx) files are needed for Alpha and Beta variants.

9.1.5 AB and UVW encoders

The HVLP-Alpha encoder circuitry (AB and UVW) requires complimentary signal compatible encoders. This means the motor encoder must output 4 signals for AB: A, A\, B and B\ and 6 for UVW.

This is no longer required in HVLP-Beta, meaning any existing encoder wiring (when changing from Alpha) must be changed accordingly. Only single ended AB or UVW signals are required.

9.2 User I/O

The user I/O connections are shown for both versions in the table below. The main difference between Alpha and Beta are that the Alpha variant only supports differential AB and UVW inputs whereas the Beta variant they are single ended. Also, in the Beta variant the sin/cos encoder inputs were shared with the AB encoder inputs.

9.2.1 HVLP Alpha user I/O

Column	Row 4	Row 3	Row 2	Row 1
A	CAN 1 L	Encoder B \	Encoder B	Resolver Cos Low
B	CAN 1 L	Encoder A \	Encoder A	Resolver Cos
C	CAN 1 termination	Encoder W \	Encoder W	Resolver Sin Low
D	CAN 1 H	Encoder V \	Encoder V	Resolver Sin
E	CAN 1 H	Encoder U \	Encoder U	Resolver excitation -
F	CAN Ground	Encoder Ground	Encoder Vcc	Resolver excitation +
G	HVIL IN 2	Encoder Cos	Encoder Sin	HVIL IN 1
H	Din 4	Din 2	Ain 3 (Motor TH 1)	Ain 1 Vcc
J	Din 3	Din 1	Ain 2 B	Ain 2 A
K	Ain Ground	HVIL Source	Ain 1 B	Ain 1 A
L	Control 0V KL31	Digital out 3	Control 0V KL31	12-24V supply KL30
M	Control 0V KL31	Digital out 4	Ignition sw KL15	12-24V supply KL30

Table 32 – HVLP Alpha Molex CMC pin allocation

9.2.2 HVLP Beta user I/O

Column	Row 4	Row 3	Row 2	Row 1
A	CAN 1 H	Din 1	CAN 1 H	Encoder Vcc
B	Encoder Ground	Resolver excitation -	Din 2	Resolver excitation +
C	CAN 1 L	CAN Ground	CAN 1 L	CAN 1 termination
D	Not Used	Din 4	Din 3	Ain 1 Vcc
E	Not Used	Resolver Cos	Encoder U	Ain 1
F	Ain 2	Resolver Cos Low	Not Used	Encoder A / Sin
G	HVIL A	Motor TH 2	Ain Ground	Motor TH 1
H	HVIL B	Resolver Sin	Not Used	Encoder V
J	Ain 3	Resolver Sin Low	Encoder B / Cos	Ignition sw KL15
K	Digital out 4	Digital out 3	Ain 4	Encoder W
L	Control 0V KL31	Not Used	Not Used	12-24V supply KL30
M	Control 0V KL31	Not Used	Not Used	12-24V supply KL30

Table 33 – HVLP Beta Molex CMC pin allocation

Chapter 10: List of Figures and Tables

Chapter 10 - List of Figures and Tables

10.1 Figures

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10.2 Tables