

HAS Series D Drive Systems Manual

Modular Drive System for Low Voltage AC Motors (Series "D")



ENGINEERING YOUR SUCCESS.

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Safety

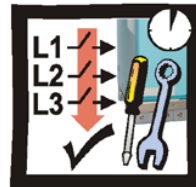
IMPORTANT Please read this information **BEFORE** installing the equipment.



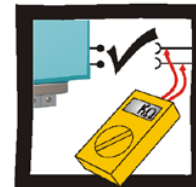
This manual is for anyone installing, operating and servicing this unit.



You must be technically competent to install and operate this unit.



Before working on the unit, isolate the main supply from terminals L1, L2 and L3 and wait 3 minutes



Disconnect the unit from circuits when doing high voltage resistance checks.

Hazard to Personnel

WARNING!

This equipment can endanger life through rotating machinery and high voltages. Failure to observe the following will constitute an **ELECTRICAL SHOCK HAZARD**.

Metal parts may reach a temperature of 70 degrees Centigrade in operation.

Before working on the equipment, ensure isolation of the main supply from terminals L1, L2 and L3. The equipment contains high value capacitors which discharge slowly after removal of the main supply. Wait for a least 3 minutes for the dc link terminals (DC+ and DC-terminal voltage with a meter to confirm that the voltage is less than 50V.

do not apply external voltage sources (main supply or otherwise to any of the braking terminals (DBR+, DBR-, DC+, INT or EXT)

Application Risk

The specifications, processes and circuitry described herein are for guidance only and may need to be adapted to user's specific application.

Parker Hannifin Manufacturing Limited does not guarantee the suitability of the equipment described in the manual for individual applications.


Non-Warranty Clause

The contents of this manual have been verified against the associated hardware and software. Although every effort has been taken to ensure the accuracy of this document it may be necessary, without notice, to make amendments or correct omissions. Parker Hannifin Manufacturing cannot accept responsibility for damage, injury, or expenses resulting therefrom.

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1 Introduction

1.1 About this document

1.1.1 Definitions

This product manual contains technical description, installation, safety and commissioning instructions and other relevant information for the 099170 inverter frames C.

1.1.2 Terms and Abbreviations

Application	A customer specific use of GVI hardware and software
Application software	Customer-specific configuration of parameters
CAN	Controller Area Network
EMC	Electromagnetic compatibility
EMF	Electromotive force
ESD	Electrostatic discharge
HW	Hardware
I2t	Overload protection based on a thermal model
Integration	Software integration means to activate all necessary functions to control the hardware design for a customer-specific application Hardware integration is the physical installation of the GVI in a customer's equipment
MCU	Motor control unit
LED	Light Emitting Diode
OEM	Original equipment manufacturer
PTC	Positive temperature coefficient
RMA	Return of Material Authorization
PWM	Pulse width modulation
SW	Software
SRP/CS	Safety-related part of a control system

1.1.3 This Revision

This revision replaces all previous revisions of this document. Parker has made every effort to ensure that this document is complete and accurate at the time of printing. In accordance with our policy of continuous product improvement, all data in this document is subject to change or correction without prior notice.

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1.1.4 Scope

This product manual presents instructions, guidelines and other information relevant to installation of the GVI frames C. For additional information see document 192-300300N3

1.1.4.1 Document Structure

This document is structured with two main target groups in mind:

Chapter 10 is intended for installation and maintenance personnel and contains step-by-step instructions for installation and maintenance of the inverter using Parker Cylinder Division's recommendations.

The other chapters in this document are mainly intended for designers and contain Parker's general recommendations and guidelines for integration of the motor controller.

1.1.5 Warning, Caution and Information Notices

Special attention must be paid to the information presented in warning, caution and information notices when they appear in this manual. Definitions of caution, warning and information notices are shown below:



WARNING

This section describes the risk of the hazard, for example High voltage - risk of personnel injury

A Warning informs the user of a hazard or potential hazard that could result in serious or fatal injury and damage to the equipment if the precautions or instructions given in the warning notice are not observed/followed.



CAUTION

This section describes the risk of the hazard, for example Risk of damage to equipment

A Caution informs the user of a hazard or potential hazard that could result in damage to the equipment if the precautions or instructions given in the caution notice are not observed/followed.




NOTE

A note contains supplemental information or references to supplemental information on a topic.

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2 Personal Safety

Parker provides this and other manuals to assist manufacturers in using the inverter properly, efficiently, and safely. Competent personnel should carry out the equipment’s installation, operation, and maintenance. A competent person is technically qualified and familiar with all safety information and established safety practices, installation process, operation, and maintenance of this equipment, and all the hazards involved.



WARNING

High voltage/high power - risk of personnel injury

The high voltage/high power levels available from a inverter can cause severe or fatal injury.

Before installation, always verify that the inverter model is correct for the vehicle’s battery supply voltage.

2.1 Safety Signs on the Equipment

Table 2 shows the signs used on Parker’s products. Use of the signs varies between products.




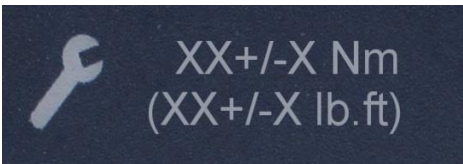
Safety sign	Description
	Take care to avoid coming in to contact with electricity.
	Read the product manual before starting any maintenance work on the equipment.
	Persons with active implanted cardiac devices shall not be in the vicinity of the equipment due to the strong electromagnetic field it generates.
	Tighten the power connection screws to the specified tightening torque (example shown).

Table 2: Safety signs used on Parker equipment

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3 Original Equipment Manufacturer Responsibility

These Parker inverter products are intended for controlling motors in electric powered mobile machines. These inverters are supplied to original equipment manufacturers (OEMs) for incorporation into their machines and machine control systems.

The OEM, through its own analysis and testing, is solely responsible for making the final selection of the system and components and assuring that all performance, endurance, maintenance, safety and warning requirements of the application are met. The OEM must analyze all aspects of the application, follow applicable standards and regulations, and follow the information concerning the product in the current product catalogue and in any other materials provided from Parker Hannifin Corporation or its subsidiaries or authorized distributors. OEMs are responsible for ensuring that the inverter is used for its intended purpose only and that their equipment functions in a safe way at all times.

To the extent that Parker Hannifin Corporation or its subsidiaries or authorized distributors provide component or system options based upon data or specifications provided by the OEM, the OEM is responsible for determining that such data and specifications are suitable and sufficient for all applications and reasonably foreseeable uses of the components or systems. The above disclaimer is being specifically brought to the user's attention and is in addition to and not in substitution to the Exclusions and Limitations on Liability which are set out in the terms and conditions of sale.

4 Technical Support

Parker supports original equipment manufacturers (OEM's) with additional information on any topic covered in this document, or for additional information about other Parker products. End customers and third parties are requested to refer to the OEM for support.

Addresses for Parker locations may be found on the back page.

5 Warranty Claim

Failure analysis and testing of the GVI is available for the OEM at Parker. The addresses may be found on the back page.

Parker does not provide any warranty or service directly to GVI end users. End users are asked to refer to the original equipment manufacturer for warranty issues, service and spare part needs.

5.1.1 Return of Material Authorization

Contact Parker before a product is returned in order to ensure an efficient handling of the product with a high level of traceability. Parker provides a return of authorization (RMA) number for returns and a form (RMA request), which describes how to proceed.

6 Product Overview

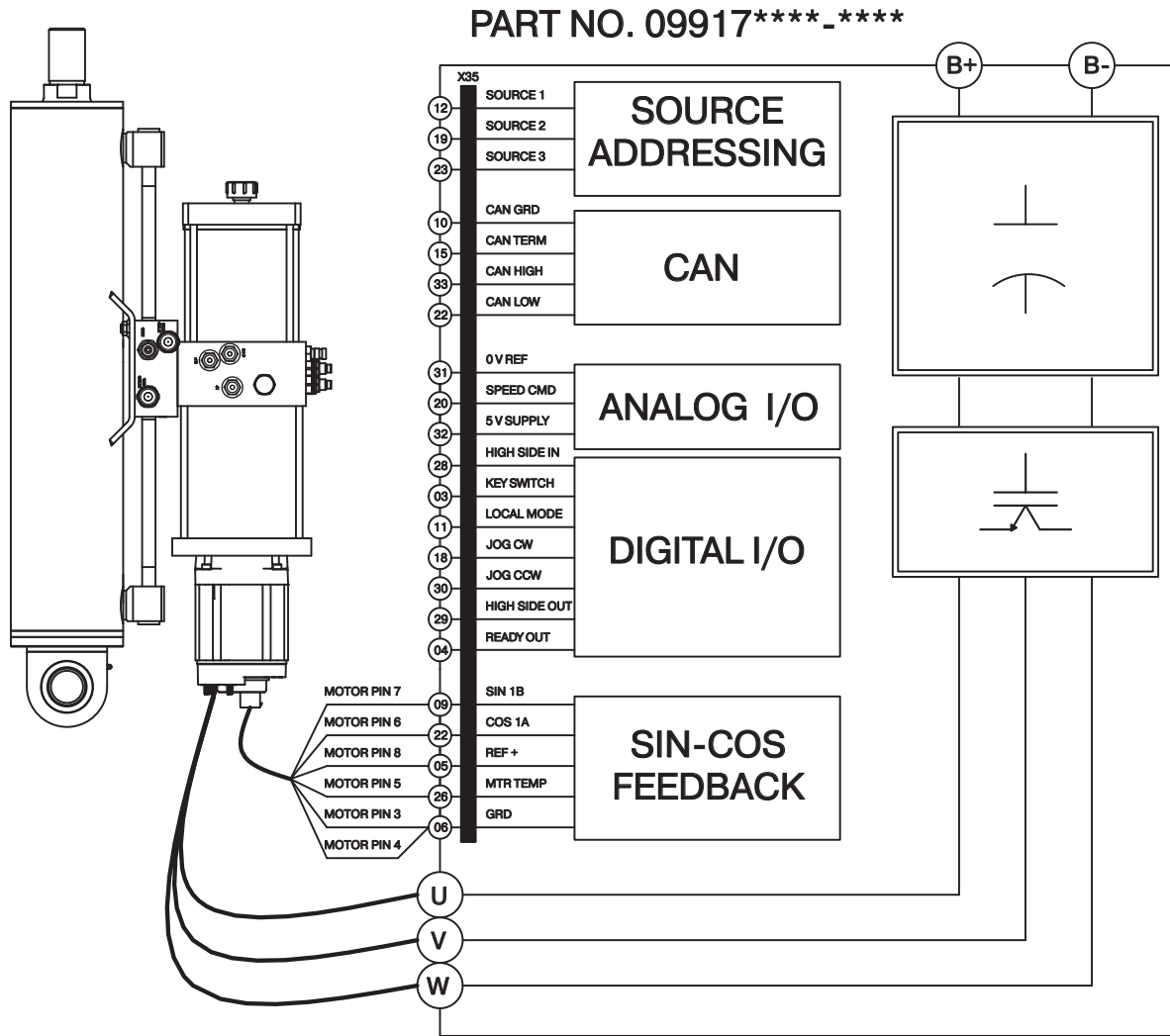


Figure 1 A typical system with the HAS and Inverter

Figure 1 shows the implementation of the Hybrid Actuation System (HAS) in a typical application.

In a typical application, the inverter converts power from a DC power source (a battery in a vehicle for example) to three phase AC power to drive a motor.

The inverter can be delivered with nominal voltages according to chapter 13.2.

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6.1 099170-XX11-XXX Inverter



Figure 2 C Frame Inverter

HAS inverters equipped with firmware for operation with HAS actuators are order in kit form. All motor variables are loaded and tied Motor configuration in model code C Frame size is adequate for HAS low voltage motors.

How to order HAS Inverters

099170 XX 11 – D09A

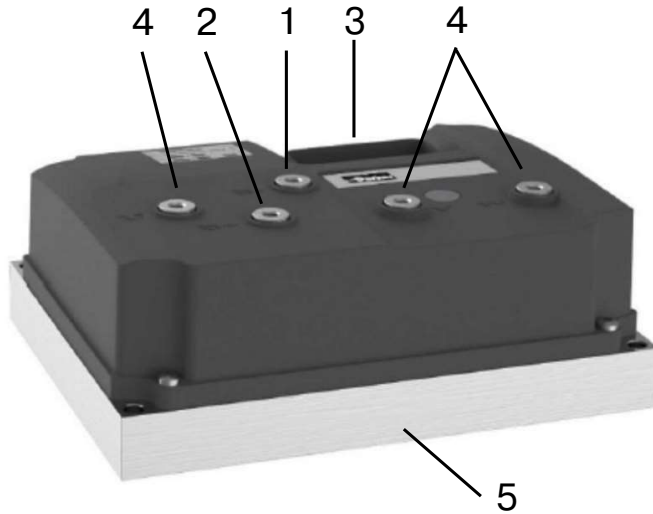
Base Drive
Up to 300
Amps

Voltage
24 = 24V
36 = 36V
48 = 48V

Heat Sink
11 = Flat Sink

Motor Configuration
D09A = 1.98 HP, 24V
D09B = 1.98 HP, 36V
D09C = 1.98 HP, 48V
D12A = 2.48 HP, 24V
D12B = 2.48 HP, 36V
D12C = 2.48 HP, 48V

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Pos	Name	Pos	Name
1	B- connection	2	B+ connection (frame dependent)
3	I/O connector	4	U1, V1 and W1 connections
5	Heat sink		

Figure 5 Connections/Components for HAS Inverter

6.2 Terminal Posts

The terminal posts are designed for ring lug connections and are supplied with threaded connections (screw connection). Fasteners are not included.

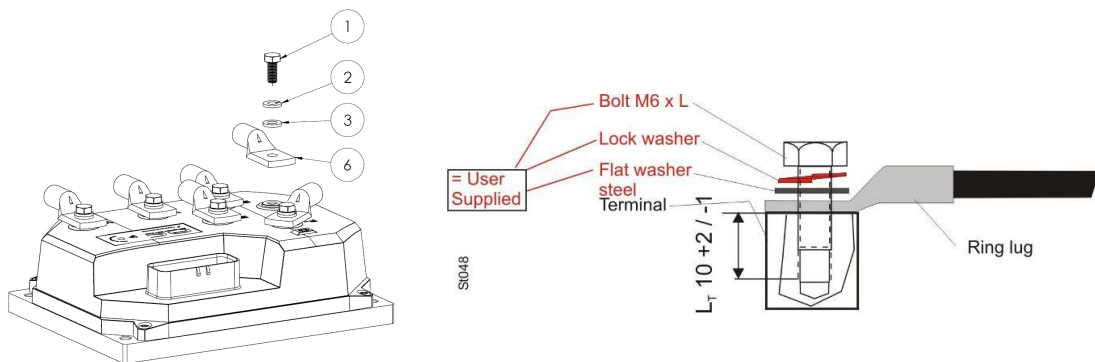


Figure 6 Terminal posts with threads

Pos	Name
1	M6 x 8.8 - Terminal (U, V, W, B- and +)
3	Flat washer 12 x 6.4 x 1.6 - 200 HV or similar.

Pos	Name
2	Disc spring DIN 2093 - 12 x 6.2 x 0.6 or similar
6	Ring lugs with 6.5 mm hole diameter

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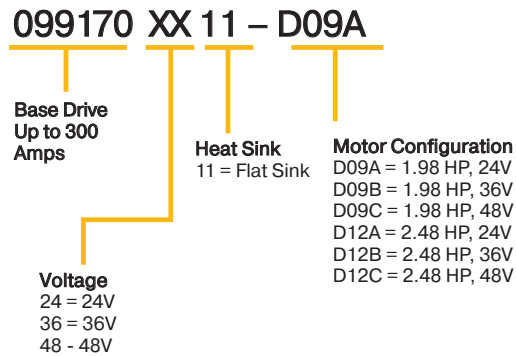
6.3 Product Identification Label

A label containing pertinent product identification information is attached to the GVI. The product label fields relevant to product identification are described in Figure 7.



Figure 7 Example of product identification label

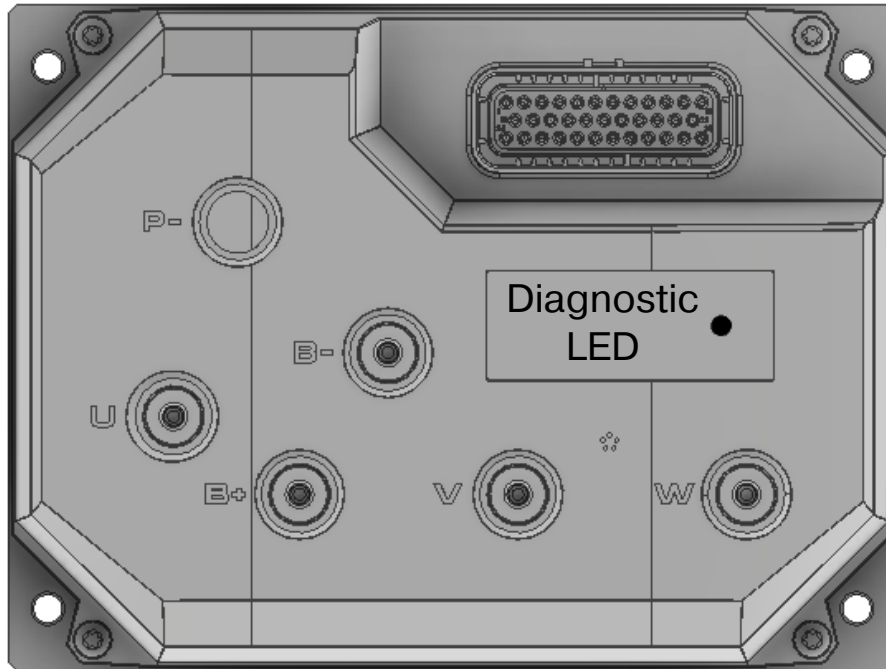
Model Code configurations



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6.4 LED Status Indicator

The LED status indicator (see 11.1), provides useful diagnostic information when troubleshooting vehicle problems (see chapter 11).



6.5 Cooling Method

The motor controller is mounted upon a heat sink, which transfers heat from the power conversion components in the motor controller to the vehicle structure or cold plate.

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7 Integration

7.1 Introduction

This chapter describes guidelines for integration of the inverter. Integration is the installation of the inverter into a vehicle.

The information is general in nature. Further instructions for mounting of the inverter are found in chapter 10.



WARNING

High voltage - risk of personnel injury and/or damage to equipment

High power levels are exposed at each of the connection posts. Protect these terminals from accidental contact which could result in personnel injury and/or short circuit.



WARNING

ESD - risk of damage to equipment

Electrostatic discharges (ESD) can damage sensitive electronic components.

Do not touch the I/O connector pins.

The inverter meets all necessary standards for ESD-protection. However, very high levels of static electricity can build up during handling of the equipment.

The built-in ESD-protection does not replace a professional and careful handling.

7.2 Dust and Liquid Ingress Prevention

The dust/moisture protection of the motor controller is only valid when the mating I/O connector is inserted and correctly assembled with appropriate cable seals.




CAUTION

Water sensitive equipment - risk of damage to equipment

The motor controller cover provides a measure of protection from liquids and particles dripping, splashing or spraying onto it. The motor controller must not be subjected to liquids under high pressure.

Do not clean the motor controller using high-pressure water.

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7.3 Cooling Requirements

The motor controller is mounted upon a solid heat sink. This is the surface that transfers heat from the power conversion components to the surroundings.

In order to cool the power conversion components efficiently, it is important to consider the thermal resistance between the heat sink and the surroundings according to chapter 7.3.1. The motor controller operating temperature is specified in chapter 13.1.



CAUTION

Operation at reduced power risk of damage to equipment and/or malfunction

Higher than intended operating temperature will cause a reduction of max output power, may result in a reduced lifetime of the motor controller and may also cause malfunction of the inverter (see chapters 9.2 and 13.2).

The Inverter is designed to operate with a maximum heat sink temperature of 85 °C. During performance testing of a new vehicle design, it is necessary to ensure that the vehicle can fulfill its environmental and performance specifications without exceeding this temperature of the motor controller. If this is not possible to achieve, the OEM should consider improving cooling of the motor controller, switching to larger motor controllers, or reduce vehicle performance.

If the **heat sink temperature exceeds 85 °C** the maximum available motor current is automatically reduced. The motor controller will still operate, with reduced performance, up to 110 °C, when an emergency shutdown will take place. It should be noted though, that the motor controller is operating outside its specification in this case, and it should only be used as a “limo home” option.

It is strongly recommended that an error message is generated and that vehicle performance is decreased if the motor controller temperature exceeds 85 °C.


7.3.1 Inverter with Flat Heat Sink

The Inverter comes with a flat (cold) plate heat sink and is cooled through surface contact with the vehicle body. Specifications for surface roughness and surface flatness where motor controller is mounted to the vehicle body must be observed (see chapter 13.5.3). Application of thermal grease to the cold plate heat sink before mounting the motor controller will achieve the best cooling effect.

The required heat sink-to-vehicle mounting surface thermal resistance shown in Table 4 must be achieved by the installation in order for the GVI to meet the published current ratings in the application.

Motor controller model	Thermal resistance
GVI Frame C	0.17 °C/W

Table 4 Required thermal resistance for flat heat sink

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7.4 Orientation



NOTE

The vibration test of the inverter does not include a horizontal mounting position with the I/O connector facing downwards.

The inverter can be mounted vertically or horizontally with the I/O connector facing upwards.

When inverters are used in an application each of the units must be arranged such that they have sufficient cooling for the required duty cycle.

Consideration should be given to accessibility and visibility of the I/O connector, terminals and on-board LED status indicator (1, Figure 8) for maintenance purposes.



Pos	Name
1	LED status indicator

Figure 8 LED status Indicator

7.5 Selecting Inverter Mounting Fasteners

Recommended screws and washers for mounting of the motor controller are specified in chapter 10.5.1.

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7.6 Wiring and Connections



WARNING

High voltage– risk of personnel injury and/or damage to equipment

High power levels are exposed at each of the connection posts. Protect these terminals from accidental contact which could result in personnel injury and/or short circuit.

This section provides schematic diagrams and related information for connecting the inverter to a HAS unit. The circuitry will allow for HAS control over J1939 CanBus or with simple discrete inputs.

7.6.1 Motor and Battery Connections

Recommended fasteners for the terminal posts are specified in chapter 10.6.



NOTE

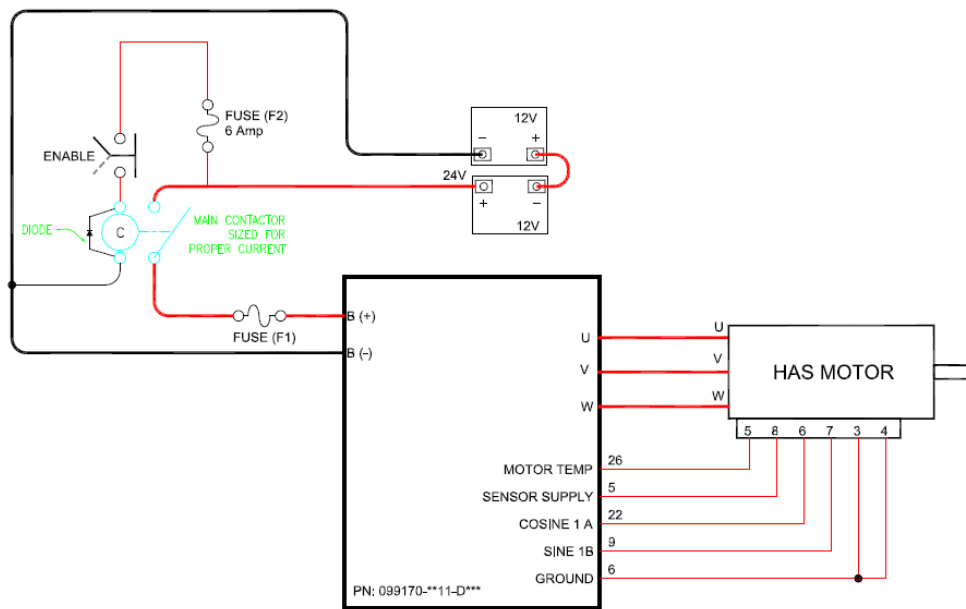
The motor connections (U, V, and W) are not interchangeable and shall be connected to the corresponding terminals on the motor.



CAUTION

Incorrect dimensioning of connections – risk of overheating

Ring lugs for motor and battery connections must be adequately rated to carry motor and battery currents. Otherwise cables and terminal posts may be overheated. See also power cable sizing guidelines in chapter 12.2.



An example of basic power wiring diagram for the motor controller and motor.

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7.6.2 Emergency

A manually operated Emergency Stop switch is required for most applications. When activated, the Emergency Stop switch de-energizes the main contactor, removing battery power from the power conversion section of the motor controllers. It should also disable the HIGH Side IN power and remove power from the Key Input.

Note: HAS Units require load control circuits for braking motion and locking load in place hydraulically.

7.6.3 Key Input (Pin 3)

The KEY_INPUT supplies battery voltage to the motor controller for its internal processor and other functions. The vehicle start Key Switch generally controls power to the KEY_INPUT and charging of the filter capacitor, see Figure 9.

The KEY_INPUT is protected against reverse polarity with a diode and has approximately 20 nF capacitance to B- for ESD protection and other filtering. This capacitance may give a high current spike at KEY_INPUT depending on the external circuit.

An internal resistor reduces the inrush current to the DC/DC main capacitor at KEY_INPUT to less than 3 A. Within that startup time period the DC/DC current ripple is drawn from the Key Switch line. The current ripple peaks may initially exceed 5 A.

The Fuse F2 in (Figure 9), should be sized according to the number of motor controllers connected to the fuse and to protect the cable area in the circuit (recommended fuse size max 10 A) and the current consumption of the KEY_INPUT (power input < 15 W).

7.6.4 High Side In (Pin 28)

Voltage to power the Ready (OD1-pin 4) should be applied to the HIGH_SIDE_IN pin 28, and the load should be connected between HIGH_SIDE_OUT. see Figure 9.

The Ready Output may be used to power the Main Contactor coil, however Parker Cylinder Division recommends operation of the main contactor to be managed by the host controller. see Figure 10.

The High side switch has maximum output current 6 Arms continuous. The high side switch (P-MOSFET) has only ON/OFF control.

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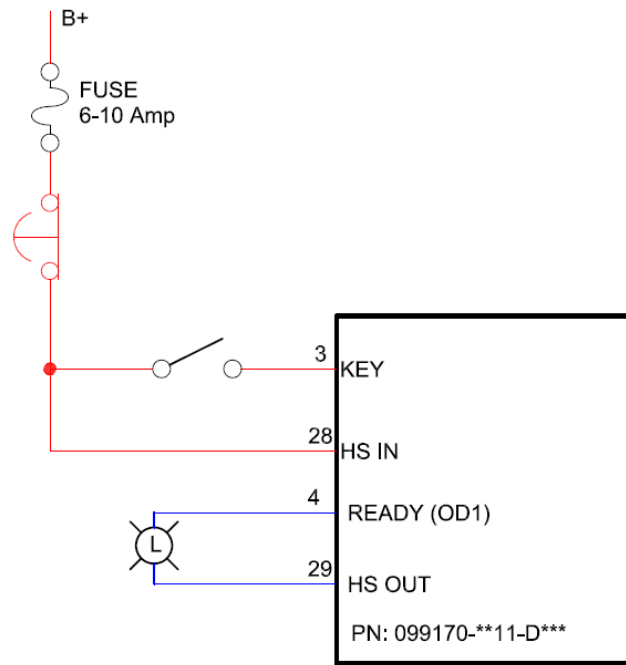


Figure 9 KEY and HIGH_SIDE_In wiring example

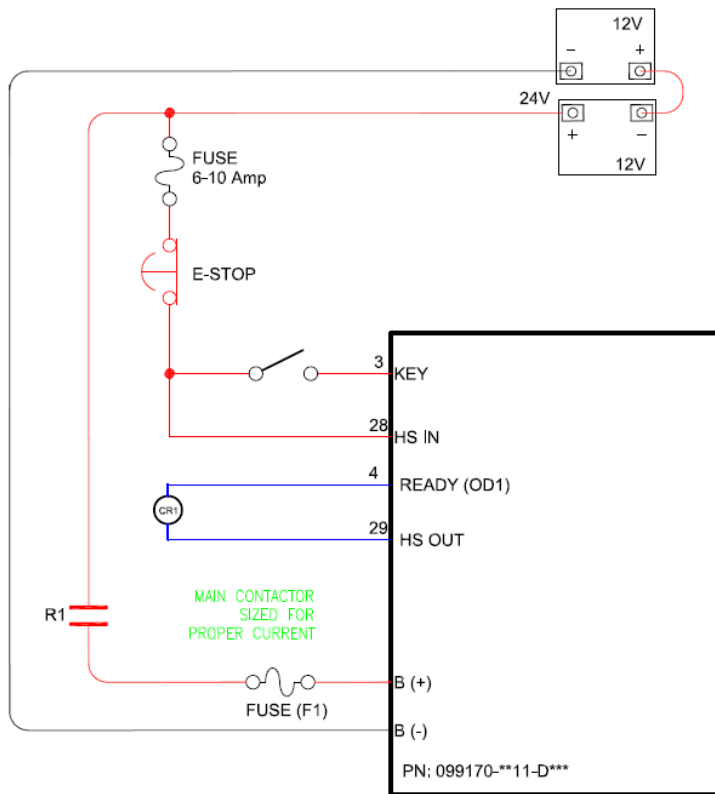


Figure 10 Ready Output to Power Main Contactor

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7.6.5 Main Contactor

The main contactor functions both as a power distribution component and as a key component in the motor controller protective interlock circuit.

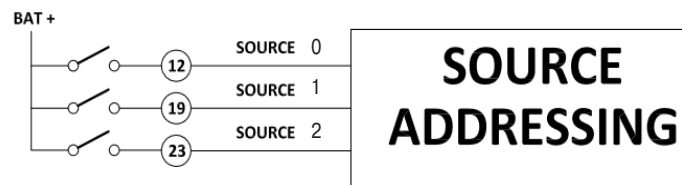
During start-up (after voltage has been supplied to the KEY_INPUT of the motor controller), the motor controller monitors the voltage of the capacitor bank. When the voltage over the capacitor bank has reached a pre-defined level, the motor controller will indicate that it is ready to switch on the main contactor. The motor controller may be configured to control the main contactor directly, with the use of Digital Output OD1 Pin 4. see Figure 10.

Preferred method is control the main contactor with the Master Control, and use Digital Output OD1 -Pin 4 as input the controller is read to receive power. This method allow Master to determine other safety interlocks required per the application.

Over CANBus, you can monitor J1939 CAN Message PGN 65302, Byte 0, bit 0 for bus confirmation that the capacitor bank has been charged. De-energize the main contactor if motion is not permitted as a result of some error/fault condition.

7.6.6 Source Addressing

Up to (8) HAS Inverters maybe placed on a common J1939 BUS. The 09917**** programmed inverter kit allows for (3) input to be wired for automatically Source Addressing assignment. This wiring schemes allows for the source addressing to be assigned by the cable harness, similar to IQAN ID tag placement in wiring harness. Source address range from 0X5B (91) through 0X62 (98).



SA0 pin 12	SA1 pin 19	SA3 pin 23	Source Address
0	0	0	0x5B [91] (Axis 0)
0	0	1	0x5C [92] (Axis 1)
0	1	0	0x5D [93] (Axis 2)
0	1	1	0x5E [94] (Axis 3)
1	0	0	0x5F [95] (Axis 4)
1	0	1	0x60 [96] (Axis 5)
1	1	0	0x61 [97] (Axis 6)
1	1	1	0x62 [98] (Axis 7)

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7.7 Inverter Typical Wiring

Figure 11 shows an example wiring diagram for a motor controller that is used as a standalone controller or J1939 CAN bus controlled inverter. With the Local Mode Input (pin 11) wired to the supply voltage all CAN Motion communications are ignored and HAS operation is achieved locally with discrete and analog logic controls.

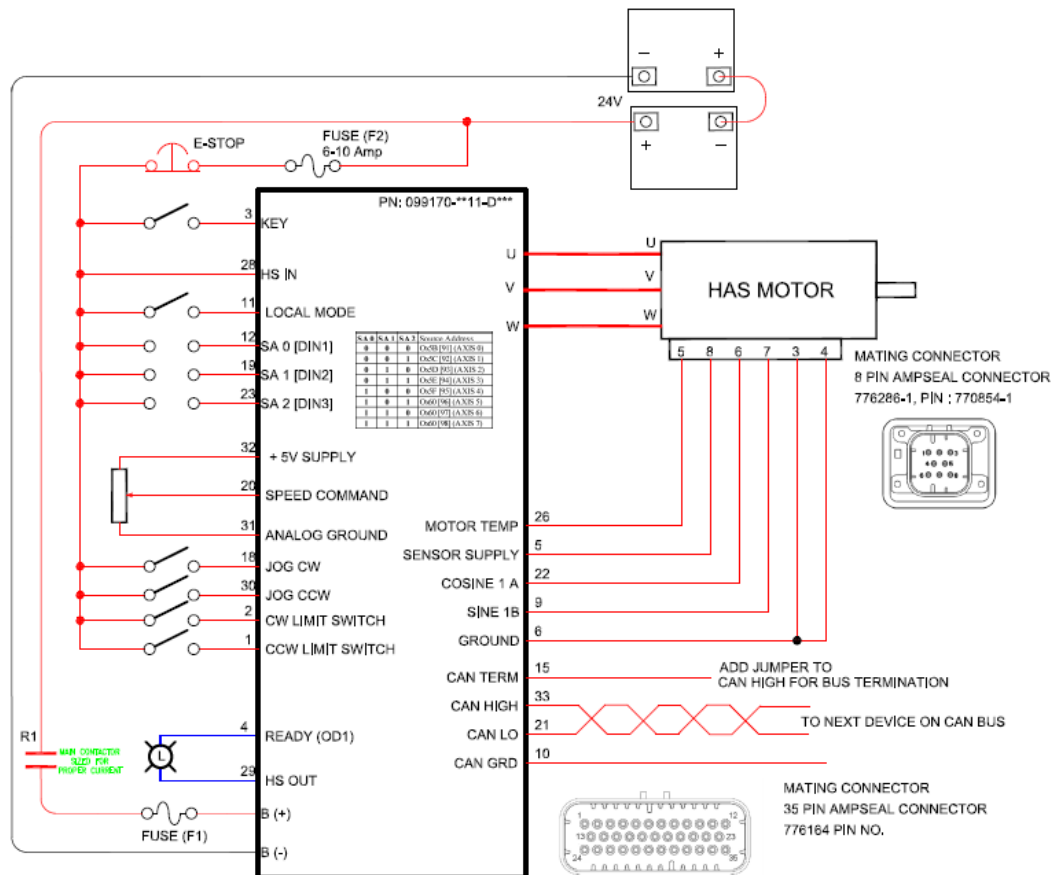


Figure 11 Typical wiring of HAS Programmed Inverter

Link Pin 15 CAN High (33) for termination if the last item on the CAN bus

Input Description

- B +** Connect to the positive lead of the Power Source, It is recommended to supply a disconnect contactor and fused source, sized for current demand on the motor. Use a faster M6 x L 8.8 mm or similar to mount cable lug to inverter.
- B-** Connect to the negative lead of the power source. Use a fastener M6X L 8.8 mm or similar to mount cable lug to inverter.
- 28 HS IN** High Side IN, connect to Power Source, supplies input power for switching logic

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Discrete Input Description- continued

- 3 Key** Connect to Power source thru a switch, upon power up, must be sequenced to be 1st operation before engaging main contactor. Confirmation of Bus Charged from “Ready” output pin 4 or J1939 PGN 65302, Byte 0, bit 0. After receipt of confirmation Bus is Charged, main contactor can be activated. Failure to wait for Bus Charged state could result in damaging controller.
- 12/19/23 SA0** Source Address Assignment, by hard wiring 3 bit scheme sets the controller source address. Multiple stand alone units should use Source Address assignment to prevent CAN errors, figure 11 assumes single configuration - Axis 0, no connection to Pins, 12, 19 and 23.
- 11 LM** Local Mode, when 24 V applied, J1939 CanBus commands will be ignored.
- 18 JCW** Jog CW, when 24V applied, Controller is enabled, speed reference point pin 20 is used to regulate HAS pump speed. HAS unit will spin Clockwise Rotation.
- 30 JCCW** Jog CCW, when 24V applied, Controller is enabled, speed reference point pin 20 is used to regulate HAS pump speed. HAS unit will spin Counter Clock Wise Rotation. If both J CW and Jog CCW are active no action will be taken.
- 1 CCW LS** Limit switch input for CCW rotation, default configuration NO contact, may inverted thru IQAN message. Stops CCW rotation (motion) when tripped. Reset when CW rotation is command.
- 2 CW LS** Limit switch input for CW rotation, default configuration NO contact, may inverted thru IQAN message. Stops CW rotation (motion) when tripped. Reset when CCW rotation is command.
- 32 +5V** Potentiometer Supply power, 5 VDC
- 20 SC** Speed Command, 0-5 V input will adjust HAS RPM Range from 0 to Max Motor Rpm. Max RPM is set in PGN 65287, Bytes 2-3.
- 31 AG** Analog Ground, Reference for 5 volt potentiometer and Speed Command values.
- 29 HS O** High Side Out, connection power supplied from High Side IN, allows for powering of external lamps, or indicators.
- 4 Ready** Shorts to ground when Bus is charged and drive is free of faults. Current limited to 2 Amps peak, 1 amp continuous.

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7.8 Sizing and selection of fuse (F1)

Selection of appropriate fuse ratings is a system design issue and falls under the OEMs responsibility. As a rule of thumb, fuse F1 should be sized based upon the maximum amp rating of the motor used as lower than inverter rating.

Motor Model	Recommended value
D09A	175 ARMS
D09B	117 ARMS
D09C	93 ARMS
D12A	175 ARMS
D12B	155 ARMS
D12C	142 ARMS

Calculate DC input current as follows:

$$I_{DC_IN} = \frac{\text{Power output [kVA]}(2 \text{ min rating}) \times 1\,000}{V_{DC}}$$

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

7.8 Sizing of logic supply fuse (F2)

The logic supply fuse (F2 in Figure 9, Figure 10, Figure 11 and Figure 12) is part of the KEY_INPUT protection, see chapter 8.3.2.


The fuse should be sized according to the number of motor controllers connected to the fuse and to protect the cable area in the circuit and the current consumption of the KEY_INPUT.

Name	Recommended value
Fuse size	Slow acting fuse 6-10 A (depending on the load)
KEY_INPUT power input	< 15 W

7.10 Preventing Reversed Polarity Connection

The power terminals shall be protected against reverse polarity even though the logic pins of the motor controller already are.

Make sure that the battery polarity is correct and do not activate the main contactor until the capacitors are charged up to the predefined voltage. The capacitors will not charge to the proper level if polarity is reversed.

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7.11 Motor Feedback Sensor

The HAS D series motors are fitted with an 8 pin Ampseal Connector. The mating connectors and sockets are supplied with the Drive kit. Mating Connector Part Number: 776286-1 and Socket Part Number: 770854-1. Connections to the Main 35 PIN Ampseal connector shown below.

To minimize the possibility of electrical noise coupling into motor feedback sensor wires, avoid routing cables next to conductors carrying high currents or high current pulses. Noise immunity may also be improved by using twisted conductor cable for the motor feedback sensor cables from motor to the motor controller. Selection of appropriate fuse ratings is a system design issue and falls under the OEMs responsibility. As a rule of thumb, fuse F1 should be sized based upon the maximum amp rating of the motor used as lower than inverter rating.

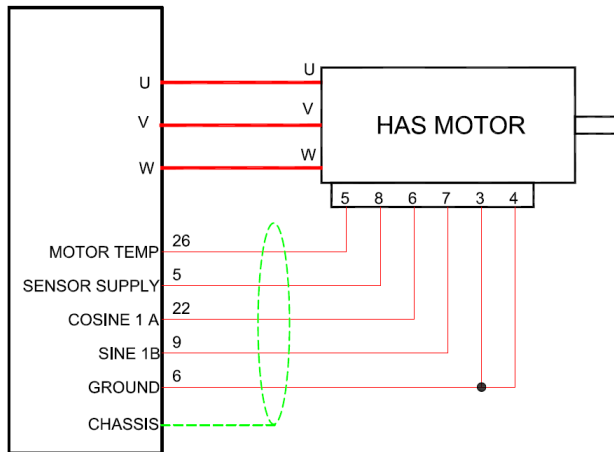


Figure 12 Motor Wiring



Figure 13 Amp Seal connector

Pinout for Amp Seal connector

Description	Pin-no
No Connection	1
No Connection	2
Supply Ground	3
Motor thermistor (PT1000), ground	4
Motor thermistor (PT1000), sense	5
Cosine output, sensor 1A	6
Sine output, sensor 1B	7
Supply voltage (11 V)	8

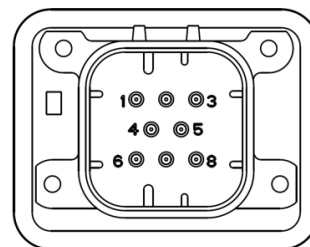


Figure 14 Motor Wiring Pinouts

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7.12 Sinusoidal Motor Speed Sensor Input

The sinusoidal speed sensor for synchronous (PMA) motors provides position, speed and direction feedback for the motor controller. The sinusoidal analog sensor produces a single-ended two-phase sinusoidal wave output (see Figure 15).

Description	Value
Phase shift	$90^\circ \pm 10^\circ$
Frequency	Max 300 Hz
Signal amplitude	Min 1 V to max 2 V
Offset	$+2.5 \text{ V} \pm 0.5 \text{ V}$

Table 6 Sinusoidal motor speed sensor input data

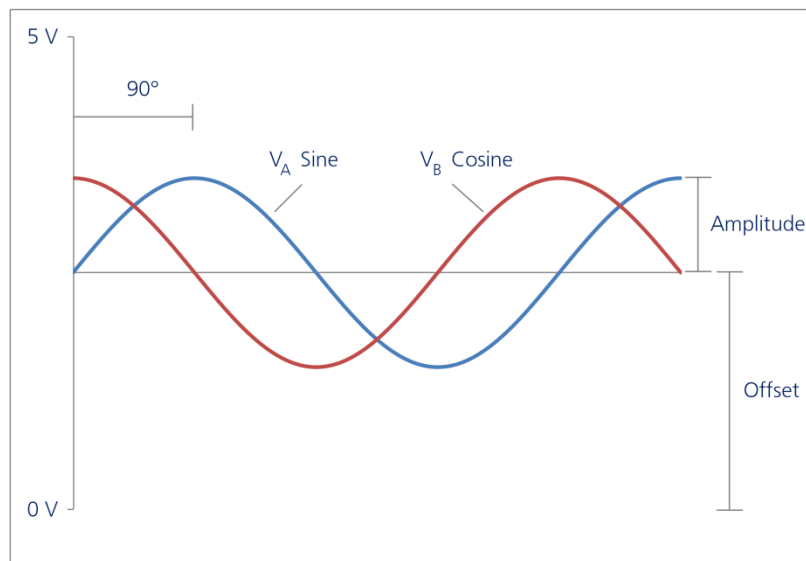


Figure 15. Sinusoidal analog sensor signal

7.13 Motor Temperature Sensor

A temperature sensor with a positive temperature coefficient embedded in the motor winding provides a means for the motor controller to monitor motor temperature. Motor temperature is used in the vector control algorithms and can also be used to protect the motor from overheating.

The standard temperature sensor supported by the inverter is the KTY 84-130.

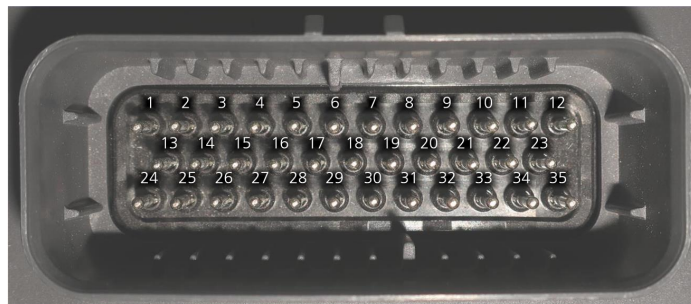


CAUTION

Incorrect wiring – risk of damage to equipment

Installation of the motor temperature sensor is done by the motor manufacturer. Contact the motor manufacturer to get the correct wiring. If the temperature sensor cables are not connected with the right polarity, the sensor readings will not be correct and overtemperature protection of the motor will not work properly.

7.14 I/O Interface



Viewed from inverter connector (Pins)

Pin	Name	Pin	Name
1	Input - CCW Limit Switch	19	Input- Source Address Bit 1
2	Input - CW Limit Switch	20	Analog Speed Input Command
3	Input - KEY_INPUT	21	CAN Low
4	Output- Ready	22	Encoder Cosine 1A
5	Encoder Supply +	23	Input- Source Address Bit 3
6	Encoder Supply -	26	Input- Motor Temp
9	Encoder Sine 1B	28	Input- High Side In
10	CAN Ground	29	Output- High Side Out
11	Input- Local Mode	30	Input- Jog CCW
12	Input- Source Address Bit 0	31	Analog Speed Input Common
15	CAN-Termination	32	Analog Speed Input -V+
18	Input - Jog CW	33	CAN High

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7.15 MTTFd

MTTFd is an extension of the MTTF calculation (mean time between failure). MTTFd is a statistical (empirical) value defined as the expected mean time for dangerous failure (d for dangerous in MTTFd). This value does not imply a guaranteed operating life or a failure-free time. Table 7 contains both MTTF and MTTFd values for different functions in the GVI.

The typical values of MTTFd in annex C of ISO 13849-1:2015 are used for calculation of the MTTFd for Parker.

7.15.1 How to Apply MTTFd Calculations in an Application

Any function in an actual application consists of more than one block. Schematically, a function can be illustrated as in Figure 16.

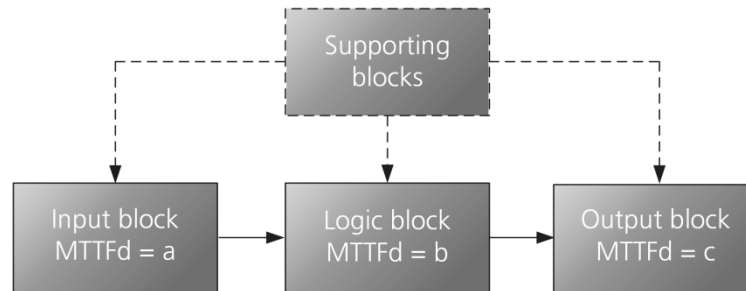


Figure 16 Principle illustration of a function

The MTTFd for a function as illustrated in Figure 16 is calculated as:

$$MTTFd = \frac{1}{a^{-1} + b^{-1} + c^{-1}}$$

7.16.2.3 MTTF and MTTFd Values for Different Functions

The external interfaces are shown schematically in Figure 17. Table 7 contains calculated MTTFd for different functions in the motor controller for Category 2 architecture, see ISO 13849-1 chapter 6.2.5.

Functions	MTTFd [years]	MTTF [years]
Input blocks		
Digital input	17 081	8 540
Analog input	9 487	4 743
Encoder input	5 028	2 514
Logic block		
Logic MCU1	1 082	541
Output block		
Open Drain output	7 350	3 675
Logic block TE (test equipment)		
Logic MCU2	N/A	716
Output block OTE		
High side switch	N/A	1 125
Non-safety blocks		
Sensor Supply	N/A	1 984
DC/DC	N/A	167
CAN	N/A	842
Motor current measurement	N/A	4 228
Motor temperature sensor interface	N/A	2 096
Power stage M	N/A	27
Power stage L	N/A	12

Table 7 MTTF and MTTFd values for different functions

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7.15.3 Power Stage

Although the power stage is an important block in the basic functionality of a motor controller, it has not been considered in all the MTTFd calculations on the grounds that faults in the power stage will not lead to a dangerous fault.

It is an inherent trait of AC motor controllers that hardware failures in the power stage do not cause uncontrolled acceleration in the motor. Instead, the motor is de-energized when the power stage is in failure mode. When designing a system around an AC motor controller though, it is important to ensure that it doesn't result in a dangerous situation in the application when the motor loses power. As an example, a system shall not depend 100 % on the motor controller to provide emergency braking power, proper overrunning load valves must be selected in HAS configuration.

7.15.4 Default Parameters, EEPROM Considerations

The EEPROM memory needs special considerations regarding safety. Most failures in the EEPROM will cause the data contained in it to be corrupt.

At startup a checksum is calculated for the parameters in each EEPROM segment. The checksum is compared to the checksum that was stored at last EEPROM write. If the two checksums do not match, it is assumed that the parameters contained in the EEPROM are not valid, and default parameters are loaded from flash memory instead.

During normal operation, the EEPROM is only used for storing time-counters, error log details, etc. RAM memory is used to contain parameters used for operation.

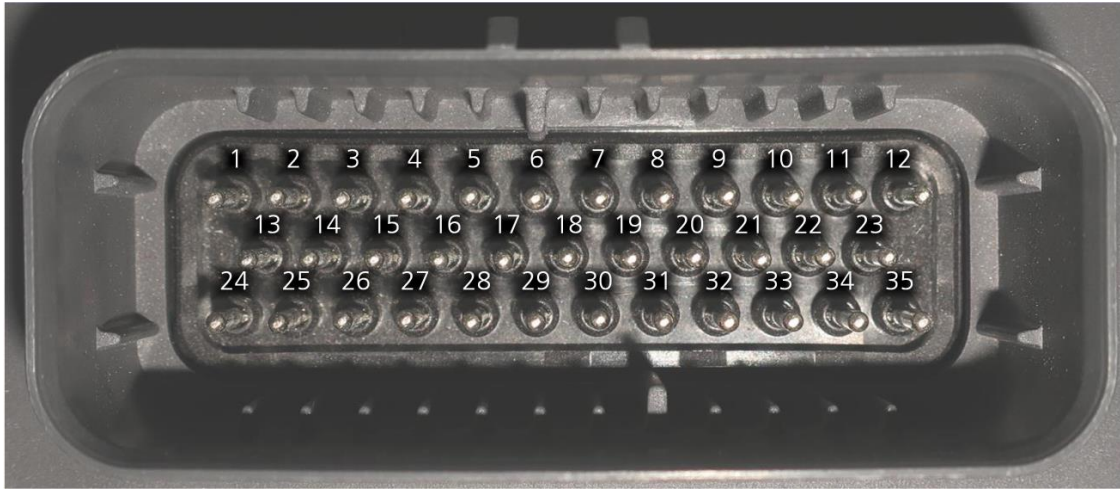
A system design where the motor controller is utilized must ensure that loading of default parameters from a flash memory doesn't cause a dangerous failure in the system.



NOTE

According to EN 1175-1:1998 + A1:2010 chapter 5.9.11 Parameter:
At startup of the vehicle, it is recommended that the truck master reads the EEPROM parameter checksum from the motor controller and checks its validity. PGN 65318 Bit 29

8.0 I/O Specifications



Pin	Name	Pin	Name
1	Input - CCW Limit Switch	19	Input- Source Address Bit 1
2	Input - CW Limit Switch	20	Analog Speed Input Command
3	Input - KEY_INPUT	21	CAN Low
4	Output- Ready	22	Encoder Cosine 1A
5	Encoder Supply +	23	Input- Source Address Bit 3
6	Encoder Supply -	26	Input- Motor Temp
9	Encoder Sine 1B	28	Input- High Side In
10	CAN Ground	29	Output- High Side Out
11	Input- Local Mode	30	Input- Jog CCW
12	Input- Source Address Bit 0	31	Analog Speed Input Common
15	CAN-Termination	32	Analog Speed Input -V+
18	Input - Jog CW	33	CAN High

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8.0 Key Input

Function

The KEY_INPUT supplies battery voltage to the motor controller for its logic circuitry. The vehicle start Key Switch often controls power to the KEY_INPUT, as shown in Figure 11 and Figure 12. The KEY_INPUT voltage is monitored.



CAUTION

Inrush current – risk of damage to equipment

The Key Switch connected to the KEY_INPUT must handle the short inrush current spike to the ESD protection capacitors. The current peak is depending on the external circuit and wire.

The KEY_INPUT is protected against reverse polarity with a diode and has a capacitance to B- for ESD protection and other filtering. This capacitance may give a high current spike at KEY_INPUT depending on the external circuit.

An internal resistor reduces the inrush current to the DC/DC main capacitor at KEY_INPUT. During the DC/DC startup, ripple current is drawn from the Key Switch line.

8.2 Digital Input

8.2.1 Function

The digital inputs are intended for connection to +/B+ via a switch, as seen in the example in Figure 11. Digital inputs assign source address, and provide local discrete operation for the HAS unit.

8.2.2 Protection

The Digital Inputs have a capacitor to B- for ESD protection.

8.2.3 Circuit

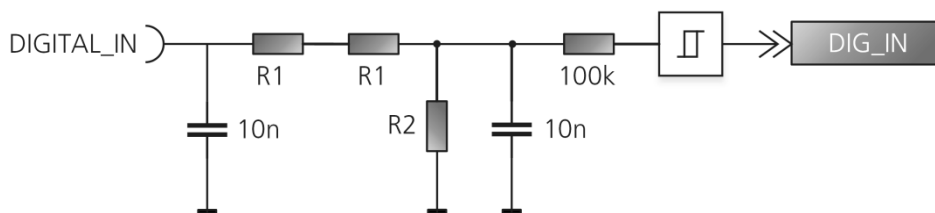


Figure 19 Schematic of the Digital input circuit



NOTE

The ID_GND pins are not protected against short circuit to +/B+.

8.3 Digital Input

8.3.1 Functions

The analog input is used for local speed control of the HAS Unit. It is only active when Digital Input, pin 11 is active. (Local Mode)

8.3.2 Protection

Analog inputs are +/B+ and B- protected and have a capacitor to B- for ESD protection.

8.3.3 Circuit



WARNING

Risk of injury and/or damage to material – missing data input

If an analog input is used as a speed reference to the motor controller, a system safety strategy must be defined.

The application software must take care of analog input errors such as “out of range”, “wire short circuit”, and “wire disconnected”.

The SENSOR_SUPPLY_GND connector pin is the ground reference for the analog inputs.

The SENSOR_SUPPLY_GND must NOT be connected to B- externally; severe noise problems or motor controller damage may occur.

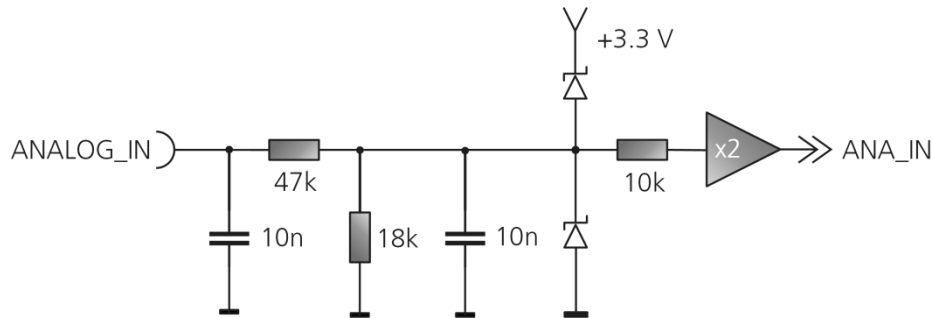


Figure 22 Schematic of the Analog input circuit

8.4 Digital Input



NOTE

Error frames counter is available in the motor controller and is a good help for diagnostic of the CAN bus noise immunity.

8.4.1 Function



WARNING

Incorrect use of isolation – risk of personnel injury

Isolation is only for increased noise immunity when running high current to the motor. The isolation must not be used for safety i.e. CAN_GND and B- shall be externally connected together in one point in the vehicle system.

Isolated CAN bus interface with Opto-couplers and internal +5 V supply from isolated DC/DC. Communication circuits with common-mode filter (choke and capacitor).

Physical Interface according to ISO 11898-2.

The CAN driver gives maximum amplitude on the CAN_HIGH to CAN_LOW signal.

Ground reference for CAN, CAN_GND, must be routed together with CAN_HIGH and CAN_LOW in the CAN-bus to avoid communication problems. There is no internal connection between CAN_GND and B- except for ESD protection and EMC suppression components.



NOTE

Using units with +3.3 V CAN drivers in this type of application with high current motor controllers is not recommended. The noise margins will be reduced and there will be high risk for CAN error frames in the CAN system.

The CAN driver gives maximum amplitude on the CAN_HIGH to CAN_LOW signal.

Ground reference for CAN, CAN_GND, must be routed together with CAN_HIGH and CAN_LOW in the CAN-bus to avoid communication problems. There is no internal connection between CAN_GND and B- except for ESD protection and EMC suppression components.



NOTE

Using units with +3.3 V CAN drivers in this type of application with high current motor controllers is not recommended. The noise margins will be reduced and there will be high risk for CAN error frames in the CAN system.

8.4.1.1 CAN_120R

CAN-cabling shall use a pair of twisted wires for CAN_HIGH and CAN_LOW wires.

The CAN-cabling shall have a characteristic impedance of 120 and both physical ends of the CAN Bus shall be terminated with 120 between CAN_HIGH and CAN_LOW for best possible noise immunity.

The motor controller has an internal 120 termination resistor connected between CAN_LOW and CAN_120R pin. To activate internal termination, CAN_120R shall be connected to CAN_HIGH with a jumper in the vehicle wire harness.

8.4.2 Protection

Protected against +/B+, B- and ESD.

8.4.3 Circuit

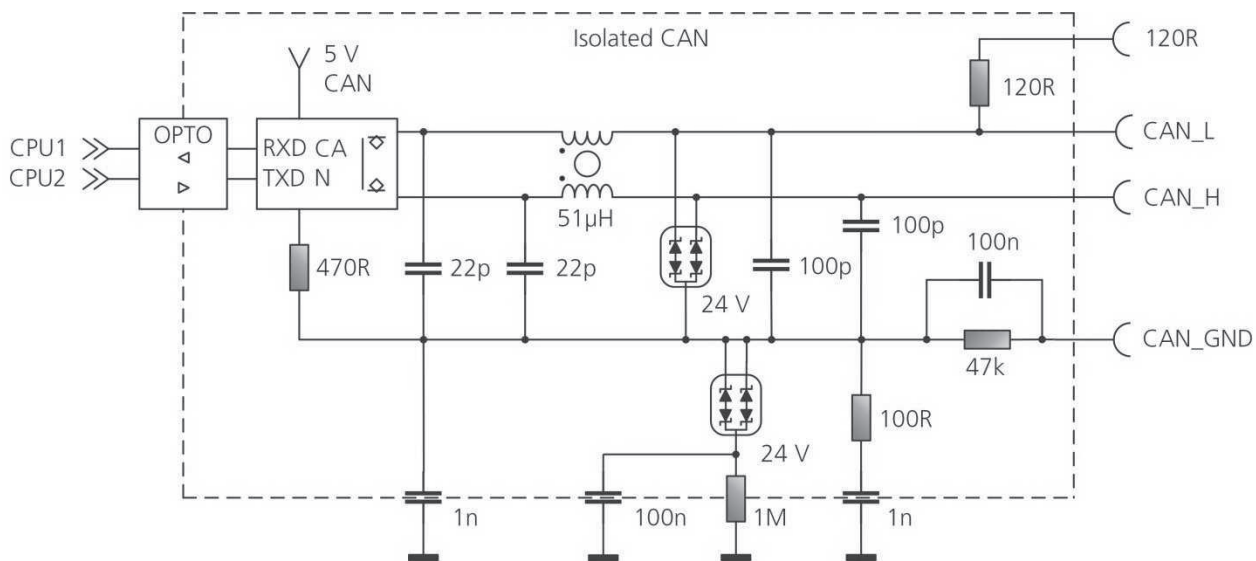
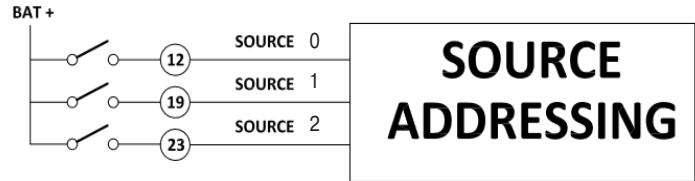


Figure 30 Schematic of the CAN circuit

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9 CAN Communications



9.1 Write Messages

HAS Programmed inverters are supplied with premapped J1939 messages for typical cylinder operations. Write messages are odd numbers and offset by Hex 0x10 (decimal 16) values. Based upon source addressing assignments in wiring configuration, use the following table to determine proper PGN values.

SA0 pin 12	SA1 pin 19	SA3 pin 23	Source Address	SA	Axis No	PGN (decimal)			
						Main Commands	Set Up	MTR Gain	Stop Macro
0	0	0	Ox5B [91] (Axis 0)	91	0	65285	65287	65289	65291
0	0	1	Ox5C [92] (Axis 1)	92	1	65301	65303	65305	65307
0	1	0	Ox5D [93] (Axis 2)	93	2	65317	65319	65321	65323
0	1	1	Ox5E [94] (Axis 3)	94	3	65333	65335	65337	65339
1	0	0	Ox5F [95] (Axis 4)	95	4	65349	65351	65353	65355
1	0	1	Ox60 [96] (Axis 5)	96	5	65365	65367	65369	65371
1	1	0	Ox60 [97] (Axis 6)	97	6	65381	65383	65385	65387
1	1	1	Ox60 [98] (Axis 7)	98	7	65397	65399	65401	65403

Figure 30 PGN axis assignments

PGN Examples are Source addressing for Axis 0, for other axis use Table Number 30 for appropriate PGN values

Main Commands

Axis 0 Data PGN 65285 [MAIN COMMANDS]									
Other Axis 1= 65301, Axis 2=65317, Axis 3=65333, Axis 4=65349, Axis 5=65365 Axis 6=65381									
Identifier		Send Method	PGN	Default Priority		Data Length (bytes)		Source Address (Typical IQAN)	
0C FF 05 + SA		Continuously	FF 05	3		8		Hex	27
								Decimal	39
Send	Receive	Subgroup Name	Byte	Bit	Length (bits)	Bits Offset [bits]	Format	Units	Resolution
	X	Enable	0	0-1	2	1	Unsigned 16	O = Disable 1= Enable 2= Reserved 3= No Action	1
	X	Speed and Direction	1-2		16	9	Signed 16	RPM (+) CW Rotation (-) CCW Rotation	1

Enable

When True, motion command accepted, bit should be set true with each message sent when motion is desired, set false in message when to decelerate and stop motion to HAS unit.

Speed & Direction

Signed Integer to set HAS speed and Direction. Value is equal to desired pump RPM. (+) Value will spin HAS pump in Clockwise rotation, (-) Value will spin pump in Counter-Clockwise rotation. Values should be clamped to a min RPM speed of 500 to ensure smooth pump flow.

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HAS Motion Setup Commands

Axis 0 Data PGN 65287 [SET UP] <i>Only need to send 1 time retained in Flash</i>									
Other Axis 1= 65303, Axis 2=65319, Axis 3=65335, Axis 4=65351, Axis 5=65367 Axis 6=65383 Axis 7=65399									
Identifier		Send Method	PGN	Default Priority		Data Length (bytes)		Source Address (Typical IQAN)	
0C FF 07 +SA		On Trigger	FF 07	3		8		Hex	27
								Decimal	39
Send	Receive	Subgroup Name	Byte	Bit	Length (bits)	Bits Offset [bits]	Format	Units	Resolution
	X	Acceleration Rate	0		8	1	Unsigned	RPM/20 mS	1
	X	Deceleration Rate	1		8	9	Unsigned	RPM/20 mS	1
	X	Max RPM	2-3		16	17	Unsigned	RPM	1
	X	CAN Bitrate	4-5		16	33	Unsigned	125 KBaud 250 KBaud (default) 400 KBaud 500 KBaud 1000 KBaud	1 kBaud

Accel Rate Unsigned integer which control the rate of HAS acceleration. Units are in RPM/ 0.02 secs ramp rate. Value of 255 = HAS Unit would reach max speed of 3000 RPM in 0.235 mS
 Default Setting: 255

Decel Rate Unsigned integer which control the rate of HAS deceleration. Units are in RPM/ 0.02 secs ramp rate. Value of 255 = HAS Unit would decelerate from max speed of 3000 RPM in 0.235 mS
 Default Setting: 200

Max RPM Unsigned integer which limits that maximum speed of the HAS unit. Value limits speed in either direction.
 Default Setting: 3000

CAN Bit Rate Reserved for Future Use, it is not recommended to overwrite value, as changing baud rate could result in loss of communications.
 Default value: 250 KBaud is suitable for IQAN integration

HAS Motor Tuning Commands

PGN 65289 [Motor Gain Settings] <i>Only need to send 1 time retained in Flash</i>									
Other Axis 1= 65303, Axis 2=65319, Axis 3=65335, Axis 4=65351, Axis 5=65367 Axis 6=65383									
Identifier		Send Method	PGN	Default Priority		Data Length (bytes)		Source Address (Typical IQAN)	
0C FF 09 +SA		On Trigger	FF 09	3		8		Hex	27
								Decimal	39
Send	Receive	Subgroup Name	Byte	Bit	Length (bits)	Bits Offset [bits]	Format	Default Values	Resolution
	X	Speed Regulator P Gain	0-1		16	1	Unsigned	750 / 200	1
	X	Speed Regulator I Gain Small	2-3		16	17	Unsigned	5 / 15	1
	X	Speed Regulator I Gain Large	4-5		16	33	Unsigned	5 / 5	1
	X	Speed Regulator D Gain	6-7		16	49	Unsigned	0	1

P Gain Unsigned integer, PMAC Motor Speed Proportional Gain
 Motor D09* Default Setting: 750
 Motor D12* Default Setting: 200

I Gain Small Unsigned integer, PMAC Motor Speed Integral Gain, Small Gain
 Setting Motor D09* Default Setting: 5
 Motor D12* Default Setting: 15

I Gain Large Unsigned integer, PMAC Motor Speed Integral Gain, Large Gain
 Setting Motor D09* Default Setting: 5
 Motor D12* Default Setting: 15

D Gain Unsigned integer, PMAC Motor Speed Derivative Gain Setting
 Default Setting: 0

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HAS Stop Motion Commands

Axis 0 Data PGN 65291 [STOP MACRO SET UP] <i>Only need to send 1 time retained in Flash</i>									
Other Axis 1= 65307, Axis 2=65323, Axis 3=65339, Axis 4=65355, Axis 5=65371 Axis 6=65387									
Identifier		Send Method	PGN	Default Priority		Data Length (bytes)		Source Address (Typical IQAN)	
0C FF 0B +SA		On Trigger	FF 0B	3		8		Hex	27
								Decimal	39
Send	Receive	Subgroup Name	Byte	Bit	Length (bits)	Bits Offset [bits]	Format	Units	Resolution
	X	End of Stroke Switch State	0	0-1	2	1	Unsigned 16	0 = NO switch Type 1= NC switch Type 2= Reserved 3= Reserved	1
	X	CW Over Current Stop	1-2		16	9	Unsigned	Motor Amps	0.1
	X	CW Over Current Time	3		8	25	Unsigned	seconds	0.1
	X	CCW Over Current Stop	4-5		16	33	Unsigned	Motor Amps	0.1
	X	CCW Over Current Time	6		8	49	Unsigned	seconds	0.1

Stroke Switch State

Binary setting used to invert HAS End of Stroke switch contact type to Normally Closed switch type. When input is seen based upon setting (0 or 1) [NO/NC switch type), HAS motion in that direction is stopped regardless of command. Active with either local discrete Jog commands or Speed and Direction commands over Can.

Default Value: 0 (Normally Open Switch type)

CW Over Current

Unsigned Integer with resolution of 0.1 amps. When set in conjunction with CW Over Current Time, stops motion when motor current (amps) exceed setting for the time duration set in CW Over Current Time message. This is useful to electronically limit the HAS Force generated by limiting pump pressure by measuring motor torque. Once motor current exceed setting for duration, logic is latched, and CW motion is prohibited until a CCW rotation is commanded.

Default Value: 175.0 amps

CW Over Current Time

Unsigned Integer with resolution of 0.1 seconds. Used in conjunction with the CW Over Current setting must exceed that value by the time duration set in this message. The purpose of this time delay is prevent and false trips due to acceleration torque or current ripple.

Default Value: 1 - (0.1 sec)

CCW Over Current

Unsigned Integer with resolution of 0.1 amps. When set in conjunction with CCW Over Current Time, stops motion when motor current (amps) exceed setting for the time duration set in CCW Over Current Time message. This is useful to electronically limit the HAS Force generated by limiting pump pressure by measuring motor torque. Once motor current exceed setting for duration, logic is latched, and CCW motion is prohibited until a CW rotation is commanded.

Default Value: 175.0 amps

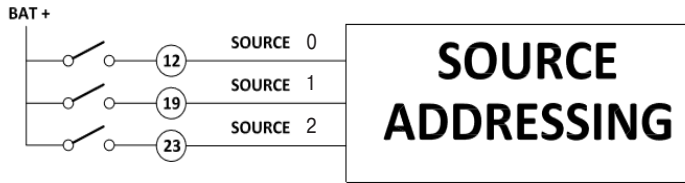
CCW Over Current Time

Unsigned Integer with resolution of 0.1 seconds. Used in conjunction with the CCW Over Current setting must exceed that value by the time duration set in this message. The purpose of this time delay is prevent and false trips due to acceleration torque or current ripple.

Default Value: 1 - (0.1 sec)

9.2 Read Messages

HAS Programmed inverters are supplied with premapped J1939 messages for typical cylinder operations. Read messages are even numbers and differentiated by Inverter Source Address wiring configuration. Based upon source addressing assignments in wiring configuration, use the following table to determine proper Source Address values.



SA0 pin 12	SA1 pin 19	SA3 pin 23	Source Address
0	0	0	0x5B [91] (Axis 0)
0	0	1	0x5C [92] (Axis 1)
0	1	0	0x5D [93] (Axis 2)
0	1	1	0x5E [94] (Axis 3)
1	0	0	0x5F [95] (Axis 4)
1	0	1	0x60 [96] (Axis 5)
1	1	0	0x60 [97] (Axis 6)
1	1	1	0x60 [98] (Axis 7)

Figure 31 Source Address assignments

Axis 0 Data PGN 65286 [HAS Motor Feedback]									
Identifier		Rate (msec)	PGN	Default			Source Address		
0C FF 06 5B		50	FF 06	3			Axis 0= 91, Axis 1 = 92, Axis 2 = 93, Axis 3 = 94		
Send	Receive	Subgroup Name	Byte	Bit	Length (bits)	Bits Offset [bits]	Format	Units	Resolution
X		Motor RPM	0-1		16	1	Signed 16	RPM	1
X		Actual Torque	2-3		16	17	Signed 16	NM	0.1
X		Actual Current (RMS)	4-5		16	33	Unsigned 16	Amps	0.1
X		Motor Temp	6-7		16	49	Signed 16	C	1

Motor RPM Signed Integer value of HAS Motor RPM. (+) Value will indicate HAS pump Clockwise rotation, (-) Value will indicate HAS pump Counter Clockwise rotation.

Torque Signed Integer value of HAS Motor torque in NM. Resolution of 0.1 NM. (+) Value will indicate HAS pump Clockwise rotational torque, (-) Value will indicate HAS pump Counter Clockwise rotational torque.

Amps RMS Unsigned Integer value of HAS Motor current draw in Arms. Resolution of 0.1 amps.

Motor Temp Signed Integer value of HAS Motor current temperature.

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9.2.1 Status Messages

Identifier		Rate (msec)	PGN	Default		Data Length (bytes)		Source Address	
0C FF 16 5B		50	FF 16	3		6		Axis 0= 91, Axis 1 = 92, Axis 2 = 93, Axis 3 = 94 Axis 4 = 95, Axis 5 = 96, Axis 6 = 97, Axis 8 = 98	
Send	Receive	Subgroup Name	Byte	Bit	Length (bits)	Bits Offset [bits]	Format	Units	Resolution
X		Ready To switch ON (Bus Charged)	0-1	0	1	1			
X		Not Used	0-1	1	1	2			
X		Power Stage Enabled	0-1	2	1	3			
X		Power Stage Tripped	0-1	3	1	4			
X		Not Used	0-1	4	1	5			
X		Current Boost Activated	0-1	5	1	6			
X		Error Active	0-1	6	1	7			
X		Warning Active	0-1	7	1	8			
X		Regeneration	0-1	8	1	9			
X		Standby	0-1	9	1	10			
X		Sleep	0-1	10	1	11			
X		Current Ability Reduced	0-1	11	1	12			
X		Open Drain Output 1	0-1	12	1	13			
X		Not Used	0-1	13	1	14			
X		Zero Speed Requested	0-1	14	1	15			
X		Not Used	0-1	15	1	16			
X		Battery Current	2-3		16	17	Signed 16	Amps	0.1
X		Battery Voltage	4-5		16	33	Unsigned 16	Volts	0.01

**Byte 0
Bit 0**

When Key Switch is set true, (digital Input, pin 3) Bit is set true when internal drive is charged and ready form Main Contactor to be energized, thus providing High Amperage to the HAS Motor Controller. Supply power to B+ before Bus Charged is active could result in damage to the inverter.

**Byte 0
Bit 6**

When True, Error is active. specific error details listed in message PGN 6318, first 4 bytes, 0-3.

**Byte 0
Bit 7**

When True, warning is active. specific warning details listed in message PGN 6318, last 4 bytes, 4-7

**Byte 0
Bit 12**

When True, "ready" discrete output is set true, digital output to confirm Bus is charged, main contactor can be energized supplying power to B + of the drive.

**Bytes
2-3**

Signed Integer value of HAS Motor amp draw from battery. Resolution of 0.1 amps, (+) Value will indicate HAS pump Clockwise rotation, (-) Value will indicate HAS pump Counter Clockwise rotation.

**Bytes
2-3**

Unsigned Integer value of HAS Motor Voltage at battery Input . Resolution of 0.01 V

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9.2.2 Error Messages

Axis 0 Data PGN 65318 [Errors and Warnings]								
Identifier		Rate (msec)	PGN	Default		Data Length (bytes)		Source Address
0C FF 26 5B		50	FF 26	3		6		Axis 0= 91, Axis 1 = 92, Axis 2 = 93, Axis 3 = 94 Axis 4 = 95, Axis 5 = 96, Axis 6 = 97, Axis 8 = 98
Send	Receive	Subgroup Name	Byte	Bit	Length (bits)	Bits Offset [bits]	Type	Description
X		Power Stage Short Circuit	0-3	0	1	1	Error	Hw detected short circuit. If the short circuit protection detects a short circuit, the power stage will be shut down. This is done by Hw without Sw interaction. The Sw will restart the power stage within 500 microseconds. If no new short is detected within 100 ms this will be regarded as a glitch. If a new short circuit signal is detected within the 100 ms this will be regarded as a "Hardware Detected Short Circuit". Event state will be set back to pending when power stage is disabled. A short circuit can be any of the following: Short circuit phase to phase Short circuit phase to ground (B-) Short circuit phase to Supply (B+)
X		DC Bus Voltage Low	0-3	1	1	2	Error	Event is set if measured voltage is below predefined level. (12V default) Hysteresis level of 1V for setting/clearing event.
X		DC Bus HIGH	0-3	2	1	3	Error	Event is set if measured voltage is above predefined level. (31.9V) Hysteresis level of 1V for setting/clearing event.
X		High Voltage Hardware Level	0-3	3	1	4	Error	Hardware detected over voltage. Level is defined by HW design.
X		DC Bus Charging Error	0-3	4	1	5	Error	Event is set if measured voltage is below predefined level after a predefined time at startup.
X		Motor Temp High	0-3	5	1	6	Error	Event is set if motor temperature is above 155 degC
X		Power Stage Temp High	0-3	6	1	7	Error	Event is set if internal Power Stage temperature is above 110 degC
X		Reserved	0-3	7	1	8	Error	
X		CAN Error	0-3	8	1	9	Error	Command message Time out, or invalid message data
X		Current Measurement/Sensor Offset	0-3	9	1	10	Error	Event is set if offset is too high. Offset is calibrated when drive is disabled. Limit is 10% of default offset that is 2047 (i.e. half of ADC full-scale value)
X		DC Motor Power Stage Short Circuit	0-3	10	1	11	Error	Hw detected short circuit. If the short circuit protection detects a short circuit, the power stage will be shut down. This is done by Hw without Sw interaction. The Sw will restart the power stage within 500 microseconds. If no new short is detected within 100 ms this will be regarded as a glitch. If a new short circuit is detected within the 500 microseconds this will be regarded as a "Hardware Detected Short Circuit".
X		Both End Limits Reached	0-3	11	1	12	Error	Both end of stroke limit swiches were detected at same time Error set an controller is disables.
X		Open Drain Output short Circuit	0-3	12	1	13	Error	Set when more than 200 mA current is measured when the output should be off Set when Peak Overcurrent or Overload is detected.
X		Over Current Error	0-3	13	1	14	Error	Event is set if measured current is too high in any of the U,V or W phases and glitch counter is above trip limit. SW algorithm: Measured current is above 150% of max allowed current (HwDetectedMaxCurrent) or if AD value or current core is close to saturation. Over current is detected if two consecutive measurements in the same phase are above the limit. OverCurrenError event is set if over current is detected and glitch counter is above trip limit (>5000). An over current error can be caused by any of the following: Short circuit or over current phase to phase Short circuit phase to ground (B-) Short circuit phase to Supply (B+)
X		Reserved	0-3	14	1	15	Error	
X		FB Sensor Supply Error	0-3	15	1	16	Error	Fault is set if 12V Sensor Supply current is too low. Limit 6mA. 12V Fault is set if Sensor Supply current is too high. Limit 68mA. Broke Wire

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9.2.2 Error Messages - Continued

Axis 0 Data PGN 65318 [Errors and Warnings]									
Identifier		Rate (msec)	PGN	Default		Data Length (bytes)		Source Address	
0C FF 26 5B		50	FF 26	3		6		Axis 0= 91, Axis 1 = 92, Axis 2 = 93, Axis 3 = 94 Axis 4 = 95, Axis 5 = 96, Axis 6 = 97, Axis 8 = 98	
Send	Receive	Subgroup Name	Byte	Bit	Length	Bits Offset	Type	Description	
X		Sensor Supply out of Range	0-3	17	1	18	Error	Internal 5V supply out of range. Valid range 4.12 to 5.88V	
X		Ext Watch Dog Tripped	0-3	18	1	19	Error	Hw watchdog in power stage. If the watchdog in the power stage is not kicked on by the CPU, the power stage will shut down.	
X		DC Current Measurement Sensor Offset	0-3	19	1	20	Error	Event is set if offset is too high. Offset is calibrated when drive is disabled.	
X		DC Current Measurement Over Current	0-3	20	1	21	Error	Event is set if measured DC current is to high. SW-algorithm: Event is set if measured current is above max current or if AD or current core is close to saturation. Two consecutive measurements must be above the limit in order to set the event.	
X		Reserved	0-3	21	1	22	Error		
X		Reserved	0-3	22	1	23	Error		
X		DC Power Stage Temp High	0-3	23	1	24	Error	Event is set if internal DC Motor Power Stage temperature is above 95 degC The DC Power Stage is tripped.	
X		DC Power Stage Sensor Error	0-3	24	1	25	Error	Event is set if internal DC Motor Power Stage temperature sensor is not connected. Event is set if internal DC Motor Power Stage temperature sensor is short circuited.	
X		Reserved	0-3	25	1	26	Error		
X		Motor Speed Error	0-3	26	1	27	Error	Event is set if motor speed is above speed limit. Event is set if the difference between the expected AC current and the measured AC current is too high.	
X		Reserved	0-3	27	1	28	Error		
X		CPU Error	0-3	28	1	29	Error	MCU was unintentionally reset due to low 3.3V power supply. MCU internal Independent watchdog not reset in time causing the MCU to reset. Set when average execution time is higher than 200U us. Set when average execution time is higher than 6000U us.	
X		CPU Checksum Error	0-3	29	1	30	Error	Fault is set if there is a checksum error on any eeprom segment with checksum.	
X		Power Stage Temp Sensor	0-3	30	1	31	Error	Event is set if internal Power Stage temperature sensor is not connected. Event is set if internal Power Stage temperature sensor is short circuited	
X		Motor Sensor Error	0-3	31	1	32	Error	Event is set if motor temperature sensor is not connected. Event is set if motor temperature sensor is short circuited.	

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9.2.3 Warning Messages

Axis 0 Data PGN 65318 [Errors and Warnings]								
Identifier		Rate (msec)	PGN	Default		Data Length (bytes)	Source Address	
0C FF 26 5B		50	FF 26	3		6	Axis 0 = 91, Axis 1 = 92, Axis 2 = 93, Axis 3 = 94 Axis 4 = 95, Axis 5 = 96, Axis 6 = 97, Axis 8 = 98	
Send	Receive	Subgroup Name	Byte	Bit	Length	Bits Offset	Type	Description
X		DC Bus Moderately Low	4-7	0	1	33	Warning	Event is set if measured voltage is below 18V Max allowed current is reduced linearly. Hysteresis level of 1 V for setting/clearing event.
X		DC Bus Moderately High	4-7	1	1	34	Warning	Event is set if measured voltage is above 26.4V Max allowed current is reduced linearly. Hysteresis level of 1 V for setting/clearing event.
X		Default Values	4-7	2	1	35	Warning	Event is set when default values are loaded from Eeprom (either due to checksum error on segment or commanded by user). Indicates that the drive is not calibrated.
X		Motor Temp Moderately Low	4-7	3	1	36	Warning	Event is set if motor temperature is below -35 degC Max allowed accelerating AC current is reduced linearly.
X		Motor Temp Moderately High	4-7	4	1	37	Warning	Event is set if motor temperature is above 145 deg C Max allowed accelerating AC current is reduced linearly.
X		Reserved	4-7	5	1	38	Warning	
X		Power Stage Temp Moderately Low	4-7	6	1	39	Warning	Event is set if internal Power Stage temperature is below -20 degC
X		Power Stage Temp Moderately High	4-7	7	1	40	Warning	Event is set if internal Power Stage temperatures above 85 degC
X		Over Current Glitch	4-7	8	1	41	Warning	Event is set if measured current is too high in any of the U, V or W phases and glitch counter is below trip limit. SW algorithm: Measured current is above 150% of max allowed current (HwDetectedMaxCurrent) or if AD value or current core is close to saturation. Over current is detected if two consecutive measurements in the same phase are above the limit. OverCurrenGlitch event is set if over current is detected and glitch counter is below trip limit (<5000). Glitch counter will then be increased (with 2000) and drive restarted. Glitch counter will be decreased (-1 every 250us) when drive is enabled without over current detected.
X		Motor Moderately High Speed	4-7	9	1	42	Warning	Event is set if motor speed is above 5000 RPM Max allowed accelerating current is reduced linearly. Only used for accelerating current.
X		Short Circuit Glitch	4-7	10	1	43	Warning	Hw detected short circuit glitch. If the short circuit protection detects a short circuit, the power stage will be shut down. This is done by Hw without Sw interaction. This event is always set whenever this happens. The Sw will restart the power stage within 500 microseconds. If a new short circuit signal is detected within the next 100 ms this will be regarded as a "Hardware Detected Short Circuit".
X		CPU Warning	4-7	11	1	44	Warning	Set when average execution time is higher than 500U us. (Slow) Set when average execution time is higher than 115U us. (Fast)
X		Default Values	4-7	12	1	45	Warning	Warning is set if new SW is downloaded, HW id is changed or there is a checksum error on the system eeprom segment.
X		Reserved	4-7	13	1	46	Warning	
X		Reserved	4-7	14	1	47	Warning	
X		Reserved	4-7	15	1	48	Warning	
X		Reserved	4-7	16	1	49	Warning	
X		Reserved	4-7	17	1	50	Warning	
X		Reserved	4-7	18	1	51	Warning	
X		Reserved	4-7	19	1	52	Warning	
X		Reserved	4-7	20	1	53	Warning	
X		Reserved	4-7	21	1	54	Warning	
X		Reserved	4-7	22	1	55	Warning	
X		Reserved	4-7	23	1	56	Warning	

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9.2.3 Warning Messages - Continued

Axis 0 Data PGN 65318 [Errors and Warnings]									
Identifier		Rate (msec)	PGN	Default		Data Length (bytes)		Source Address	
0C FF 26 5B		50	FF 26	3		6		Axis 0= 91, Axis 1 = 92, Axis 2 = 93, Axis 3 = 94 Axis 4 = 95, Axis 5 = 96, Axis 6 = 97, Axis 8 = 98	
Send	Receive	Subgroup Name	Byte	Bit	Length	Bits Offset	Type	Description	
X		CW Over Current Reached	4-7	24	1	57	Warning	Clockwise End Limit reached by detected Over Current as set in Stop Macro	
X		CCW Over Current Reached	4-7	25	1	58	Warning	Counter-Clockwise End Limit reached by detected Over Current as set in Stop Macro	
X		CW End of Stroke Limit	4-7	26	1	59	Warning	Clockwise End Limit reached by detected end of stroke discrete input	
X		CW End of Stroke Limit	4-7	27	1	60	Warning	Counter- Clockwise End Limit reached by detected end of stroke discrete input	
X		Reserved	4-7	28	1	61	Warning		
X		Reserved	4-7	29	1	62	Warning		
X		Reserved	4-7	30	1	63	Warning		
X		Reserved	4-7	31	1	64	Warning		

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9.4 Motor Winding Monitoring

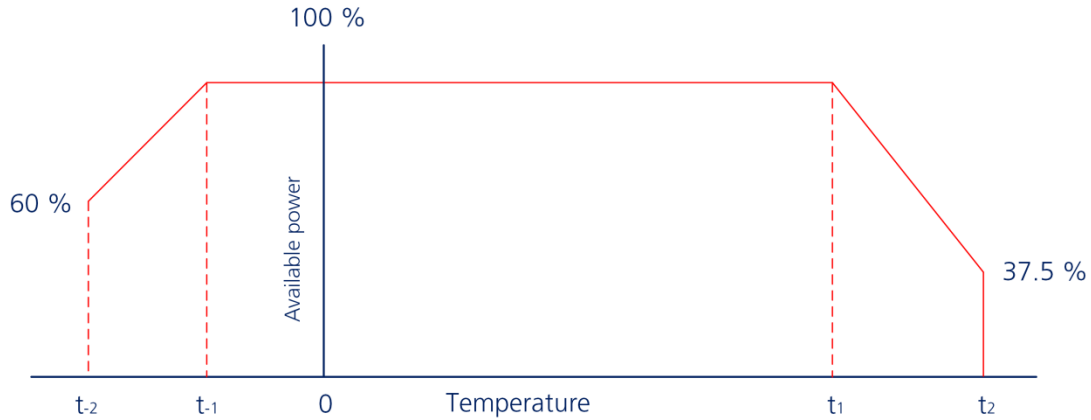


Figure 32 Available power as a result of motor winding monitoring

To protect the motor from damage, power will be reduced at temperatures outside the normal operating temperature range as seen in Figure 32, and the motor controller will shut down completely at t₂. Temperatures t₁, t₂, t₋₁, and t₋₂ are configurable in the application software.

9.5 Motor Current Monitoring

- Current measurement for V and W motor-phase, calibrated to ± 10 %.
- Overload and short circuit protection.

9.6 Voltage Monitoring

Voltage monitoring data	24V	48V
Voltage measurement range [V ±5%]	0-33.6	0-67.2
Overvoltage trip [V ±5%]	33.6	67.2
Battery voltage range [V ±0.5%]	20.4-26.4	40.8-52.8

Table 13 Voltage Monitoring data

9.7 CAN Timeout Monitoring

There is a CAN communication watchdog timeout for CAN monitoring, default timeout value is 50 ms.

9.8 Pre-Charge Timeout Monitoring

During power up, the filter capacitor bank must be pre-charged within 10 sec (default value).

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10 Installation and Maintenance Instructions

10.1 Introduction

This chapter contains general instructions for installation and maintenance of the inverter. Fasteners and tightening torques for mounting of the inverter must be specified in accordance with Chapter 7. Fasteners for connection of the terminal posts on the motor controller must be specified according to chapter 10.6.

The actual procedures for installation and maintenance of the motor controller in a specific vehicle may vary from what is presented here or include additional steps. It is the responsibility of the vehicle manufacturer to develop detailed instructions for installation and maintenance of the inverter in the target vehicle.



CAUTION

Sensitive equipment – risk of damage to equipment

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

Do not clean the motor controller using high-pressure water.



NOTE

The maintenance instructions in this chapter are general-purpose procedures that do not address vehicle-specific requirements. Personnel performing maintenance should consult the vehicle manufacturer's instructions, which always supersede the instructions in this document.

10.2 Periodic Inspection & Preventive Maintenance

The recommended periodic preventive inspection and maintenance for the motor controller and associated components are minimal. Parker recommends that the below are performed regularly. Refer also to chapter 3.



WARNING

High voltage risk of electric shock

Disconnect the battery power supply before starting any work on the vehicle.



WARNING

High voltage risk of personnel injury and/or damage to equipment

To prevent personnel injury and protect the inverter from possible damage due to voltage transients, the inverter the instruction below. Do not short the +/B+ to B- terminal as this may cause an arc.



WARNING

Hot surfaces risk of personnel injury

After operation of the motor controller, the heat sink may be too hot to touch. Allow it to cool before performing any maintenance work on the motor controller.




CAUTION

Water sensitive equipment risk of damage to equipment

Do not clean the motor controller using high-pressure water.

1. Wait 5 minutes for the internal filter capacitors to self-discharge, or apply a 1000 (10W) resistance between +/B+ and B- terminals for 15 seconds to discharge the filter capacitors. Check that the voltage between +/B+ and B- is below 10V DC.
2. Check screw torque at terminal posts according to the values in chapter 10.6
3. Inspect and, if necessary, remove dirt and debris from the fins of the motor controller heat sink to ensure cooling performance is maintained.
4. Reconnect the battery power supply.

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10.4 Inverter Removal



WARNING

High voltage risk of personnel injury and/or damage to equipment

To prevent personnel injury and protect from possible damage due to voltage transients, the inverter's internal filter capacitors shall be discharged as described in the chapter 10.2. Do not short the +/B+ to B- terminal as this may cause an arc.



WARNING

Hot surface risk of personnel injury

After operation of the motor controller, the heat sink may be too hot to touch. Allow it to cool before performing any maintenance work on the motor controller.



CAUTION

ESD risk of damage to equipment

Connecting both the motor controller heat sink and the frame of the motors to the chassis of the truck is recommended for EMC and ESD purposes.

5. Disconnect the battery power supply.
6. Wait 5 minutes for internal filter capacitors to self-discharge, or apply a 100Ω (10W) resistance between +/B+ and B- terminals for 15 seconds to discharge the filter capacitors. Check that the voltage between +/B+ and B- is below 10Vdc.
7. Depress locking latch on I/O connector housing and remove mating connector from the motor controller.
8. Mark the power cables to the terminals on the inverter (Table 15) in order to reconnect them properly again.
9. Remove the power cables from the +/B+, B-, U, V and W terminals.
10. Remove the screws securing the motor controller to the vehicle.

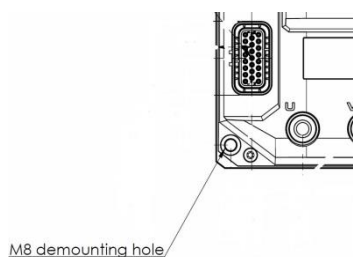


Figure 33 Demounting hole and slot

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10.5 Inverter Installation



WARNING

High voltage – risk of electric shock

Disconnect the battery power supply before starting any work on the vehicle.



WARNING

Electric arc – Risk of personnel injury and/or damage to equipment

Do not short the +/B+ to B- terminal as this may cause an arc.



CAUTION

ESD – risk of damage to equipment

Connecting both the motor controller heat sink and the frame of the motors to the chassis of the truck is recommended for EMC and ESD purposes.



NOTE

Orientation of the motor controller is the OEM responsibility. See Chapter 7.4.

1. Verify that the item number stated on the motor controller label is correct for the application.
2. For flat heat sink version, apply thermal grease evenly over the heat sink surface.
3. Mount the motor controller to the vehicle body and tighten the screws slightly. See chapter 10.5.1 for recommended screws.
4. Tighten the screws. Applied torque must be defined by OEM according to material used in vehicle body.
5. Insert mating I/O connector plug to the motor controller.
6. Perform initial start-up according to the procedure described in chapter 10.7.1.
7. Connect the power cables to the terminals (Table 15) on the motor controller according to chapter 10.6.
8. Reconnect the battery power supply.

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10.5.1 Assembly Material for Inverter Mounting

Analog inputs are +/B+ and B- protected and have a capacitor to B- for ESD protection.

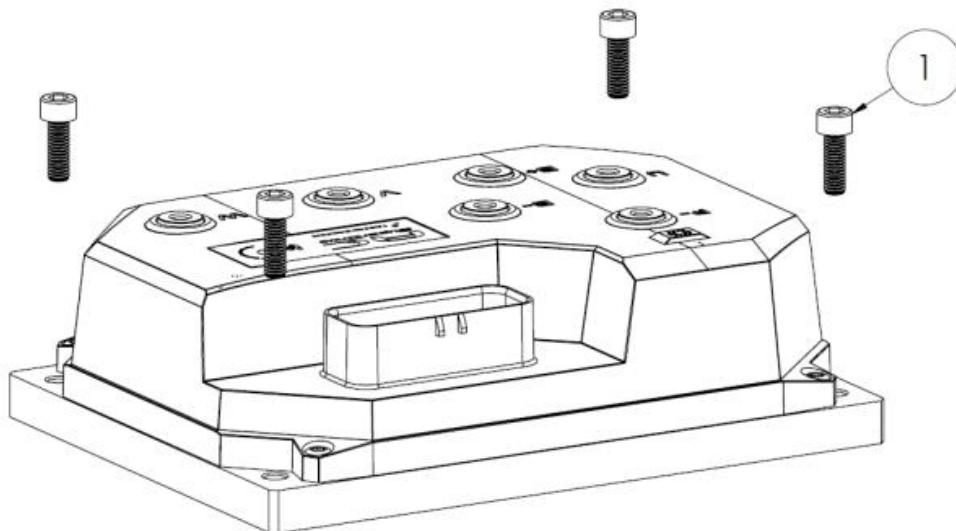


WARNING

High current risk of personnel injury and/or damage to equipment

To avoid burning or overheating of the high-current terminals, ensure that:

- The correct torque is applied to screws or nuts at production.
- The proper mounting screw length is used in installations with threaded studs



Pos	Description
1	4x MC6S M6 x L 8.8 fzb (DIN 912) MRT M6 x L 8.8 fzb, T30 (DIN 7985) bolts or equivalent (1/4 UNC) bolts.
	Thermal grease Electrolube HTC or Dow Corning 340, approximate 9 grams (only for flat heat sink).

Table 14 Assembly materials for inverter

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10.6 Connecting Terminal Posts



WARNING

High current – risk of personnel injury and/or damage to equipment

To avoid burning or overheating of the high-current terminals, ensure that the correct torque is applied to screws or nuts at production, and that proper screw length is used.



WARNING

High current – risk of personnel injury and/or damage to equipment

To avoid burning or overheating of the high-current terminals, the washers used for the optional on-board fuse shall be made of tin-plated copper.



NOTE

The motor connections (U, V, and W) are not interchangeable and shall be connected to the corresponding terminals on the motor.

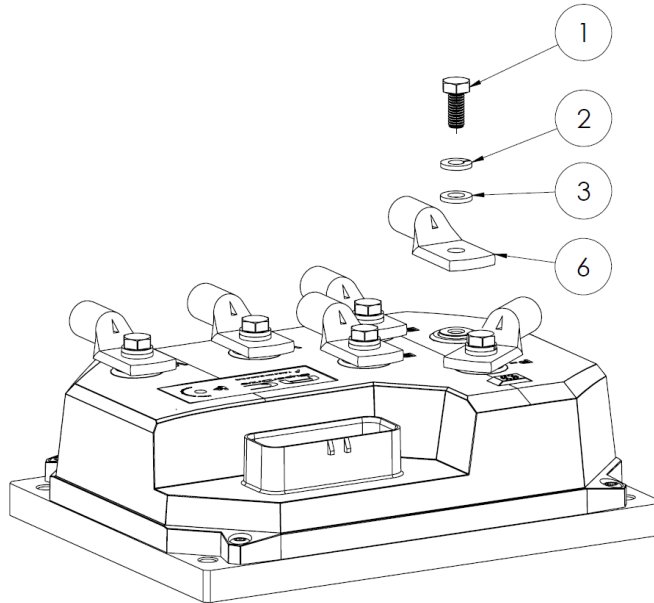


NOTE

Make sure that the battery polarity is correct and do not activate the main contactor until the capacitors are charged up to the predefined voltage. The capacitors will not charge to the proper level if polarity is reversed.

10.6.1 Terminals with Threads

Figure 35 shows the assembly order for the terminal connection fasteners.



Crimp ring lugs (4) onto the motor & battery wires, and then secure the lugs to terminal posts using M6 bolts (1), washers (2) & (3),

Pos	
1	6x Hexalobular socket head cap screw ISO 14579 - M6 x L 8.8 or similar.
2	6x Disc spring DIN 2093 - 12 x 6.2 x 0.6 or similar.
3	6x Flat washer ISO 7089 12 x 6.4 x 1.6 - 200 HV or similar.
6	6x Ring lugs with 6.5 mm hole diameter for battery and motor connection

Use a torque wrench with a 10 mm socket. Tighten bolts to 7.5 ± 0.5 Nm.

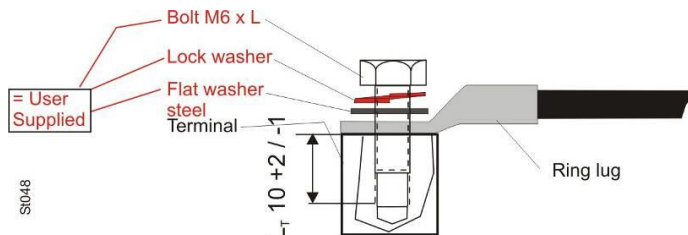


Figure 35. Wire Connection

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10.7 Start-up and Commissioning

10.7.1 Checks Before Initial Power up


Perform the following checks before applying power to a motor controller for the first time:

1. Verify that the proper part number for the application has been installed. Verify that the vehicle battery voltage matches the motor controllers Nominal DC Supply Voltage rating listed on the product identification label (Figure 7).
2. Verify that the correct source address wiring is set for specific axis.
3. Verify that all power and signal wiring to the inverter are correctly connected. Refer to chapter 7 for power connections.
4. Verify that connections to battery and motor terminals are tightened with appropriate torque (chapter 7.6).
5. Verify that the control I/O plug is fully mated and latched into position with the mating connector on the inverter.
6. Verify that the inverter is correctly fused for the application.

10.7.1 Verifying Motor Controller Readiness for Operation

The following procedure can be used to verify that a inverter is functional and able to communicate over CAN bus.

1. Apply logic power to the GVI by applying battery power to KEY_INPUT.
2. Verify that the LED status indicator (see chapter 11.1) on the inverter lights steadily in on condition.
3. If the indicator is flashing or off , it indicates an error/warning or other fault condition within the inverter(see chapter 11.1).

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11 Troubleshooting

Refer to the Error and Warning can messages for details Refer chapter 9.1.3

11.1 LED Status Indicator

The LED status indicator (Figure 8) informs about the current state of the motor controller according to Table 16.

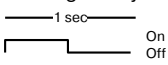
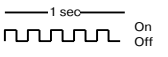
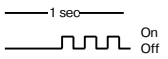
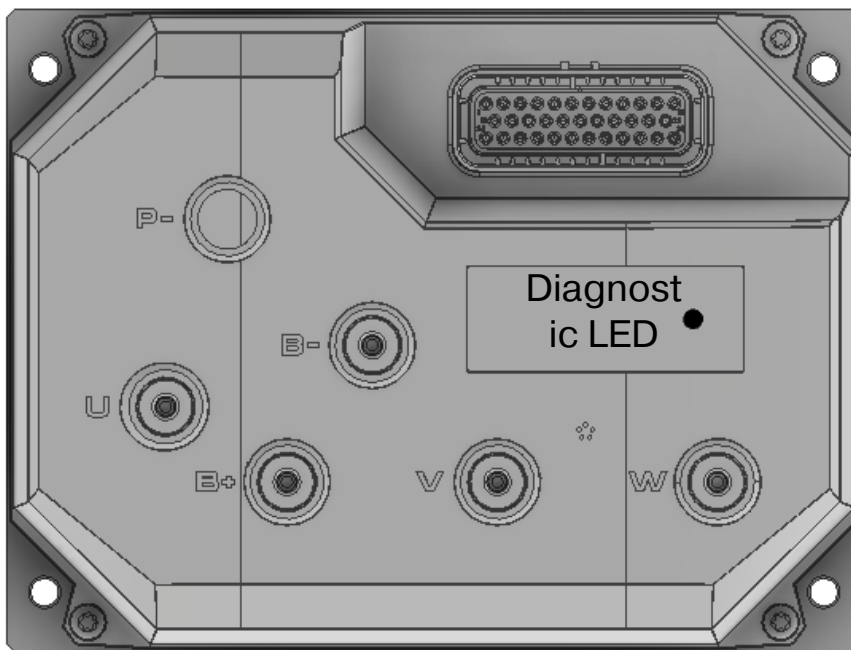
LED status indicator appearance	Drive condition
Off	Inverter is not powered, or powered but not functional.
On (steady light)	Inverter is fully operational with no error condition.
Blinking very slowly (0.1 Hz)	Sleep mode is activated.
Blinking slowly 	A warning condition is active. This may cause the Inverter to reduce maximum available output power to the motor.
Blinking rapidly 	An error condition is active. This may cause the Inverter to shut down output power to the motor.
Intermittent blinking 	Inverter is in software boot mode, caused either by an on-going software download or by missing or corrupt application software.

Table 16 LED status indicator



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12 General Considerations for System Design



CAUTION

Inappropriate design and assembly – risk of damage to equipment

Follow the design and assembly guidelines in this manual to avoid damage to the equipment.

In the following section some common causes for issues in a system are listed, together with general information about how to avoid them through proper system design.

12.1 I/O and Signal Cables

- Physically separate power cables from signal cables. As a rule of thumb a minimum separation of 100 mm is necessary.
- Do not connect any signal ground to the vehicle frame, (even if it is allowed in a 24 V system according to EN1175-1).
- Verify noise levels on analog and digital inputs with different functions in operation running (traction, hydraulics etc.).
- Very high currents may circulate between motor controller and battery. Even if cables are dimensioned correctly, this may lead to a significant voltage drop between motor controller B- terminal and negative terminal on the battery. This means that there may be voltage differences between GND references of different units in a control system. Therefore, connecting all wires of sensors supplied by the motor controller directly to the intended I/O connector pins is strongly recommended.
- Consider alternative paths for I/O cables to find the one that generates least noise (EMC).
- To avoid damage to PCs or other external instrumentation connected to the mains network, use a galvanic isolated CAN interface.

12.2 Power Cables

- Keeping the cable length between KEY_INPUT and battery is less than 10 m is recommended.
- To avoid burning or overheating of the high-current terminals, ensure that the cable connection has been made according to chapter 10.6, and that the correct torque has been applied to screws or nuts. If the power cables are not connected properly, excess heat will be generated that could damage both the motor controller and other equipment in the vehicle.
- If a washer is used between cable-lug and terminal, it must be made of copper. Otherwise overheating may occur.
- Use sturdy ring lugs made from a tube (see Figure 38), not from a plate.


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Figure 38 Ring lug made from tube

- Parker recommends cable type Huber+Suhner Radox 155(S) with EMI screen.
- Motor and battery cables must be thermally dimensioned to match the power of the motor controller and the motor. The European standard EN1175-1 (A 3.7) requires that the battery connector parts shall withstand 90 °C. It is recommended as a minimum that all cables are chosen to withstand this temperature.
- Cable selection depends on the cable construction, so refer to the cable manufacturers technical documentation to choose wire sizes.
- All high voltage cables shall be shielded.
- The cable area shall be selected to match the 1 hour rating of the application, EN1175-1 (5.10.2). The rating of a chosen cable diameter will vary between manufacturers and shall consider derating for installation method and ambient temperature.
- As an alternative to unwieldy, heavy gauge cables, two thinner cables in parallel can be used. The total area of the thinner cables shall exceed the area of the large cable.

12.3 Electromagnetic Compatibility (EMC)



Figure 39 Example of copper braids for grounding of motors

- In order to minimize potential EMC issues, both inverter and motor must have good electrical connection to the vehicle frame. A low ohm connection for high frequency (EMC), between inverter heat sink and vehicle frame, is achieved by clamping the heat sink firmly to an unpainted part of the vehicle frame and/or connecting the heat sink to the frame with a tinned copper braid (Figure 39)

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Battery (positive and negative) cables shall be routed in parallel to each other and close together. If they are routed in different directions they could create a loop that leads to EMC issues. Motor cables shall also be routed in parallel and clamped to the vehicle frame, to avoid them acting as antennas for EMC. If motor cables must be routed in the air, a metallic plate or a cable connected to the frame could reduce the EMC if placed in parallel with the motor cables.

- To consider at customer's production: If a separate battery on a cart is used, connect the frame of the cart to the frame of the truck to avoid different charge levels on truck frame and battery. Different levels may damage the unit or motor.
- The GVI has an internal resistor ($\geq 10 \text{ M}\Omega$) to prevent build-up of excessive static electricity between frame and battery. The resistor is connected to battery minus and to the vehicle frame through the GVI heat sink.

12.4 Start-up & turn off Sequences

The electrolytic capacitor bank of the motor controller unit must be charged. The time required to charge the capacitor is monitored and an error is set if it takes longer than the set limit for charge time-out (default value is 10 seconds).

The capacitor bank is charged when the Key discrete input is set high.

Confirmation that capacitor are charged may be monitored via Can messages and or from discrete output at pin 4.

When Capacitor are charged, the main contactor supplying power to B+ may be enabled.

12.5 Motor

- Check that the motor phase cables are correctly connected to U, V & W
- If the motor runs only at slip-speed or oscillates, check the speed-sensor wires.

13 Product Specifications

13.1 General

Description	Value
Supported motor types	Synchronous AC (PMAC)
Switching frequency	4, 8, 12, 16 kHz
Operating stator current frequency	0-599 Hz
Control modes	Speed (rpm), Torque (Nm), Current (ARMS) or Voltage (VDC)
Communication	CAN - J1939
Connector	AMP SEAL 23-pin
Operating temperature	-40 °C to + 55 °C (-40 °F to +131 °F)
Storage temperature	-40 °C to +85 °C (-40 °F to +185 °F)

13.2 Current and Power Output Ratings

Nominal DC supply voltage [V DC]	Rated current (S2 2 min) [ARMS]**	Rated current (S2 1 h) [ARMS]***	Rated power (S2 2min) [kVA]**	Rated power (S2 1h) [kVA]***
24	350	150	10	4
48	280	120	17	7

** 2 minute rating at 8 kHz switching frequency and 25°C ambient temperature.

*** 1 h rating at 8 kHz switching frequency, 40°C ambient temperature, and 6 m/s air flow through finned heat sink (not supplied)

13.3 DC Supply Voltage Ratings

Nominal DC supply voltage [VDC]	Operating range [VDC]	Instantaneous min. (< 100 ms) [VDC]	Instantaneous max. (< 10 s) [VDC]
24	18-32	12	34
48	33-63	24	68

** 2 minute rating at 8 kHz switching frequency and 25°C ambient temperature

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13.4 I/O Interface Technical Data

13.4.1 Key Input

Description	Value
Function	
Inrush current (reduced by internal resistor)	< 3 A
The current ripple peaks may initially exceed 5 A.	
Circuit	
Capacitor (B-) for ESD protection	Approximately 20 nF

13.4.2 Digital Inputs

Refer to Figure 19

Description	Value
Function	
Threshold level for logic low	< 2 V
Threshold level for logic high	> 10 V
Maximum input voltage	+ / B+
Circuit	
Input impedance	
GVI 24– 48 V	8.1 ± 0.5 kΩ
GVI 80 V	27 ± 1 kΩ
GVI 96 V	40 ± 2 kΩ
Input capacitance (ESD protection)	10 nF

13.4.3 Analog Inputs

Refer to Figure 22

Description	Value
Function	
Analog to Digital Converter	12 bit ADC, input range 0-5 V
Maximum input frequency	100 Hz
Circuit	
Input impedance	65 kΩ
Input capacitance (ESD protection)	10 nF

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13.4.5 Open Drain Output

Refer to Figure 24

Description	Value
Function	
Open drain output continuous (hold) current	1 A (Open drain 4, 5, 6)
Open drain output peak (pull) current (max 200ms)	2 A (Open drain 4, 5, 6)

13.4.6 High Side In and Out

Refer to Figure 26

Description	Value
Function	
High_side minimum input voltage	+10 V
High side switch maximum output current	6 A continuous
Maximum allowable ripple current	2 A continuous
Circuit	
Capacitor for ESD protection	10 nF

13.4.7 Motor temperature Measurement Input

Refer to Figure 27

Description	Value
Circuit	
Internal voltage reference	+3.0 V
Input impedance	1.65 kΩ
Difference voltage measurement gain	2.2
Input capacitance	10nF

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13.4.8 Sensor Supply

Refer to Figure 28

Description	Value
Sensor supply 1	+12 V
Sensor supply 2	+5 V
Maximum output current	75 mA

Table 18 Sensor supply

13.4.9 CAN

Refer to Figure 30

Description	Value
Function	
Internal supply	+5 V
Data rate	125, 250 or 500 kbit/s
CAN driver supply	+5 V
Circuit	
Capacitor (B-) for ESD protection	1 nF
Termination resistor	120 Ω

13.5 Physical Characteristics

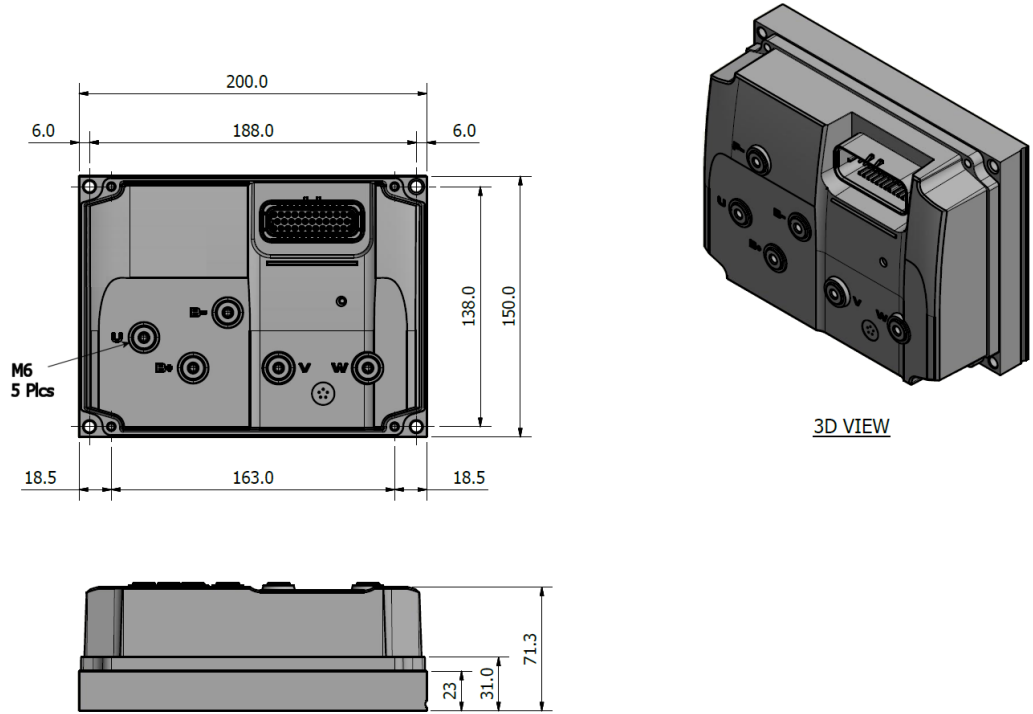
13.5.1 Weight

Weight accuracy is ± 10 % depending on actual product configuration.

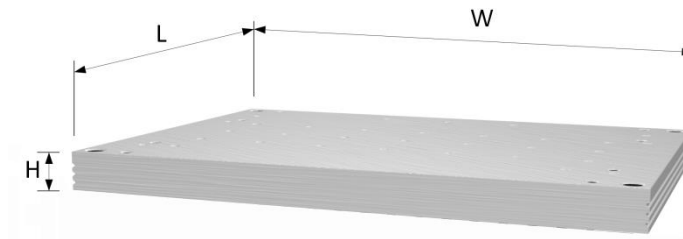
GVI Size [Kg]	
Frame C	2.3

13.5.2 Dimensions

13.5.2.1 Frame C



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Size	H x W x L [mm]
Frame C	12.5 x 200 x 150

Figure 40 Width (W) and length (L) of heat sinks

13.5.3 Surface Requirement

The mounting surface in the vehicle shall fulfill this requirement for full rating according to chapter 13.2.

Frame	Tolerance	Roughness
All models	\square 0.1/200x150 mm	$\sqrt{1.6}$ Ra 1.6

Table 19 Roughness and flatness requirement

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13.6 Environmental Testing & Standards Appliance

13.6.1 General

Subject	Standard
Protection class	IP65 Test IEC 60529 (with mating connector installed)
Standard	UL 583 and EC declaration of incorporation of partly completed machinery according to EN1175-1

13.6.2 Temperature

Subject	Standard
Cold storage -40 °C, 16 hours	IEC 60068-2-1 test Ad
Dry heat storage +85 °C, 16 hours	IEC 60068-2-2 test Bd
Cold operation -40 °C, 16 hours	IEC 60068-2-1 test Ad
Dry heat operation 65 °C, 16 hours	IEC 60068-2-2 test Bd
Change of temperature -40 °C to 65 °C, 20 cycles	IEC 60068-2-14 test Na

13.6.3 Humidity

Subject	Standard
Humidity steady-state 85 % Rh 85 °C, 500 hours	IEC 60068-2-78 test Cab
Composite temperature/humidity cyclic test -10 °C to +65 °C	IEC 60068-2-38 test Z/AD

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13.6.4 Mechanical Tests

Subject	Standard																								
Random vibration accelerated life	EN 60068-2-64 test Fh																								
	<table border="1"> <thead> <tr> <th>Frequency [Hz]</th> <th>Acceleration PSD [g²/Hz]</th> </tr> </thead> <tbody> <tr><td>5</td><td>0.02</td></tr> <tr><td>8</td><td>0.025</td></tr> <tr><td>14</td><td>0.2</td></tr> <tr><td>25</td><td>0.0</td></tr> <tr><td>100</td><td>5</td></tr> <tr><td>200</td><td>0.0</td></tr> <tr><td>250</td><td>5</td></tr> <tr><td>275</td><td>0.075</td></tr> <tr><td>350</td><td>0.02</td></tr> <tr><td>500</td><td>0.02</td></tr> <tr><td>Total g RMS</td><td>3.5</td></tr> </tbody> </table>	Frequency [Hz]	Acceleration PSD [g ² /Hz]	5	0.02	8	0.025	14	0.2	25	0.0	100	5	200	0.0	250	5	275	0.075	350	0.02	500	0.02	Total g RMS	3.5
Frequency [Hz]	Acceleration PSD [g ² /Hz]																								
5	0.02																								
8	0.025																								
14	0.2																								
25	0.0																								
100	5																								
200	0.0																								
250	5																								
275	0.075																								
350	0.02																								
500	0.02																								
Total g RMS	3.5																								
	Duration 50 h in each																								
	The drive was in operation during the test																								
Bump 25 G	2 500 positive and 2 500 negative half sine pulses with acceleration of 25 g, pulse length 6 ms for all 3 octagonal axis, tested as described in EN60068-2-27 Test Ea																								
Shock 50 G	5 positive and 5 negative half sine pulses with acceleration of 50 g, pulse length 6 ms for all 3 octagonal axis, tested as described in EN 60068-2-27 test Ea																								

13.6.5 EMC


Subject	Standard
Emission	According to EN12895, Industrial Trucks (radiated emission test EN 55022 class B)
Immunity 27 -1 000 MHz 20V/m	EN 61000-4-3
ESD 8 kV contact 15 kV air discharge	EN 61000-4-2
Electrical fast transient /burst	EN61000-4-4 level 2

13.6.6 Isolation

Subject	Standard
24-48 V B- terminal to heat sink 500 Vac (50 Hz/60 Hz)	According to EN 1175-1 and UL 583

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Safety Guide for Selecting and Using Hydraulic, Pneumatic Cylinders and Their Accessories

WARNING:  **FAILURE OF THE CYLINDER, ITS PARTS, ITS MOUNTING, ITS CONNECTIONS TO OTHER OBJECTS, OR ITS CONTROLS CAN RESULT IN:**

- Unanticipated or uncontrolled movement of the cylinder or objects connected to it.
- Falling of the cylinder or objects held up by it.
- Fluid escaping from the cylinder, potentially at high velocity.

THESE EVENTS COULD CAUSE DEATH OR PERSONAL INJURY BY, FOR EXAMPLE, PERSONS FALLING FROM HIGH LOCATIONS, BEING CRUSHED OR STRUCK BY HEAVY OR FAST MOVING OBJECTS, BEING PUSHED INTO DANGEROUS EQUIPMENT OR SITUATIONS, OR SLIPPING ON ESCAPED FLUID.

Before selecting or using Parker Hannifin Corporation (the Company) cylinders or related accessories, it is important that you read, understand and follow the following safety information. Training is advised before selecting and using the Company's products.

1.0 General Instructions

1.1 Scope – This safety guide provides instructions for selecting and using (including assembling, installing, and maintaining) cylinder products. This safety guide is a supplement to and is to be used with the specific Company publications for the specific cylinder products that are being considered for use.

1.2 Fail Safe – Cylinder products can and do fail without warning for many reasons. All systems and equipment should be designed in a fail-safe mode so that if the failure of a cylinder product occurs people and property won't be endangered.

1.3 Distribution – Provide a free copy of this safety guide to each person responsible for selecting or using cylinder products. Do not select or use the Company's cylinders without thoroughly reading and understanding this safety guide as well as the specific Company publications for the products considered or selected.

1.4 User Responsibility – Due to very wide variety of cylinder applications and cylinder operating conditions, the Company does not warrant that any particular cylinder is suitable for any specific application. This safety guide does not analyze all technical parameters that must be considered in selecting a product. The hydraulic and pneumatic cylinders outlined in this catalog are designed to the Company's design guidelines and do not necessarily meet the design guideline of other agencies such as American Bureau of Shipping, ASME Pressure Vessel Code etc. The user, through its own analysis and testing, is solely responsible for:

- Making the final selection of the cylinders and related accessories.
- Determining if the cylinders are required to meet specific design requirements as required by the Agency(s) or industry standards covering the design of the user's equipment.
- Assuring that the user's requirements are met, OSHA requirements are met, and safety guidelines from the applicable agencies such as but not limited to ANSI are followed and that the use presents no health or safety hazards.
- Providing all appropriate health and safety warnings on the equipment on which the cylinders are used.

1.5 Additional Questions – Call the appropriate Company technical service department if you have any questions or require any additional information. See the Company publication for the product being considered or used, or call 1-847-298-2400, or go to www.parker.com, for telephone numbers of the appropriate technical service department.

2.0 Cylinder and Accessories Selection

2.1 Seals – Part of the process of selecting a cylinder is the selection of seal compounds. Before making this selection, consult the "seal information page(s)" of the publication for the series of cylinders of interest.

The application of cylinders may allow fluids such as cutting fluids, wash down fluids etc. to come in contact with the external area of the cylinder. These fluids may attack the piston rod wiper and or the primary seal and must be taken into account when selecting and specifying seal compounds.

Dynamic seals will wear. The rate of wear will depend on many operating factors. Wear can be rapid if a cylinder is mis-aligned or if the cylinder has been improperly serviced. The user must take seal wear into consideration in the application of cylinders.

2.2 Piston Rods – Possible consequences of piston rod failure or separation of the piston rod from the piston include, but are not limited to are:

- Piston rod and or attached load thrown off at high speed.
- High velocity fluid discharge.
- Piston rod extending when pressure is applied in the piston retract mode.

Piston rods or machine members attached to the piston rod may move suddenly and without warning as a consequence of other conditions occurring to the machine such as, but not limited to:

- Unexpected detachment of the machine member from the piston rod.
- Failure of the pressurized fluid delivery system (hoses, fittings, valves, pumps, compressors) which maintain cylinder position.
- Catastrophic cylinder seal failure leading to sudden loss of pressurized fluid.
- Failure of the machine control system.

Follow the recommendations of the "Piston Rod Selection Chart and Data" in the publication for the series of cylinders of interest. The suggested piston rod diameter in these charts must be followed in order to avoid piston rod buckling.

Piston rods are not normally designed to absorb bending moments or loads which are perpendicular to the axis of piston rod motion. These additional loads can cause the piston rod to fail. If these types of additional loads are expected to be imposed on the piston rod, their magnitude should be made known to our engineering department.

The cylinder user should always make sure that the piston rod is securely attached to the machine member.

On occasion cylinders are ordered with double rods (a piston rod extended from both ends of the cylinder). In some cases a stop is threaded on to one of the piston rods and used as an external stroke adjuster. On occasions spacers are attached to the machine member connected to the piston rod and also used as a stroke adjuster. In both cases the stops will create a pinch point and the user should consider appropriate use of guards. If these

external stops are not perpendicular to the mating contact surface, or if debris is trapped between the contact surfaces, a bending moment will be placed on the piston rod, which can lead to piston rod failure. An external stop will also negate the effect of cushioning and will subject the piston rod to impact loading. Those two (2) conditions can cause piston rod failure. Internal stroke adjusters are available with and without cushions. The use of external stroke adjusters should be reviewed with our engineering department.

The piston rod to piston and the stud to piston rod threaded connections are secured with an anaerobic adhesive. The strength of the adhesive decreases with increasing temperature. Cylinders which can be exposed to temperatures above +250°F (+121°C) are to be ordered with a non studded piston rod and a pinned piston to rod joint.

2.3 Cushions – Cushions should be considered for cylinder applications when the piston velocity is expected to be over 4 inches/second.

Cylinder cushions are normally designed to absorb the energy of a linear applied load. A rotating mass has considerably more energy than the same mass moving in a linear mode. Cushioning for a rotating mass application should be reviewed by our engineering department.

2.4 Cylinder Mountings – Some cylinder mounting configurations may have certain limitations such as but not limited to minimum stroke for side or foot mounting cylinders or pressure de-ratings for certain mounts. Carefully review the catalog for these types of restrictions.

Always mount cylinders using the largest possible high tensile alloy steel socket head cap screws that can fit in the cylinder mounting holes and torque them to the manufacturer's recommendations for their size.

2.5 Port Fittings – Hydraulic cylinders applied with meter out or deceleration circuits are subject to intensified pressure at piston rod end.

The rod end pressure is approximately equal to:

$$\frac{\text{operating pressure} \times \text{effective cap end area}}{\text{effective rod end piston area}}$$

Contact your connector supplier for the pressure rating of individual connectors.

3.0 Cylinder and Accessories Installation and Mounting

3.1 Installation

3.1.1 – Cleanliness is an important consideration, and cylinders are shipped with the ports plugged to protect them from contaminants entering the ports. These plugs should not be removed until the piping is to be installed. Before making the connection to the cylinder ports, piping should be thoroughly cleaned to remove all chips or burrs which might have resulted from threading or flaring operations.

3.1.2 – Cylinders operating in an environment where air drying materials are present such as fast-drying chemicals, paint, or weld splatter, or other hazardous conditions such as excessive heat, should have shields installed to prevent damage to the piston rod and piston rod seals.

3.1.3 – Proper alignment of the cylinder piston rod and its mating component on the machine should be checked in both the extended and retracted positions. Improper alignment will result in excessive rod gland and/or cylinder bore wear. On fixed mounting cylinders attaching the piston rod while the rod is retracted will help in achieving proper alignment.

3.1.4 – Sometimes it may be necessary to rotate the piston rod in order to thread the piston rod into the machine member. This operation must always be done with zero pressure being applied to either side of the piston. Failure to follow this procedure may result in loosening the piston to rod-threaded connection. In some rare cases the turning of the piston rod may rotate a threaded piston rod gland and loosen it from the cylinder head. Confirm that this condition is not occurring. If it does, re-tighten the piston rod gland firmly against the cylinder head.

For double rod cylinders it is also important that when attaching or detaching the piston rod from the machine member that the torque be applied to the piston rod end of the cylinder that is directly attaching to the machine member with the opposite end unrestrained. If the design of the machine is such that only the rod end of the cylinder opposite to where the rod attaches to the machine member can be rotated, consult the factory for further instructions.

3.2 Mounting Recommendations

3.2.1 – Always mount cylinders using the largest possible high tensile alloy steel socket head screws that can fit in the cylinder mounting holes and torque them to the manufacturer's recommendations for their size.

3.2.2 – Side-Mounted Cylinders – In addition to the mounting bolts, cylinders of this type should be equipped with thrust keys or dowel pins located so as to resist the major load.

3.2.3 – Tie Rod Mounting – Cylinders with tie rod mountings are recommended for applications where mounting space is limited. The standard tie rod extension is shown as BB in dimension tables. Longer or shorter extensions can be supplied. Nuts used for this mounting style should be torqued to the same value as the tie rods for that bore size.

3.2.4 – Flange Mount Cylinders – The controlled diameter of the rod gland extension on head end flange mount cylinders can be used as a pilot to locate the cylinders in relation to the machine. After alignment has been obtained, the flanges may be drilled for pins or dowels to prevent shifting.

3.2.5 – Trunnion Mountings – Cylinders require lubricated bearing blocks with minimum bearing clearances. Bearing blocks should be carefully aligned and rigidly mounted so the trunnions will not be subjected to bending moments. The rod end should also be pivoted with the pivot pin in line and parallel to axis of the trunnion pins.

3.2.6 – Clevis Mountings – Cylinders should be pivoted at both ends with centerline of pins parallel to each other. After cylinder is mounted, be sure to check to assure that the cylinder is free to swing through its working arc without interference from other machine parts.

4.0 Cylinder and Accessories Maintenance, Troubleshooting and Replacement

4.1 Storage – At times cylinders are delivered before a customer is ready to install them and must be stored for a period of time. When storage is required the following procedures are recommended.

4.1.1 – Store the cylinders in an indoor area which has a dry, clean and noncorrosive atmosphere. Take care to protect the cylinder from both internal corrosion and external damage.

4.1.2 – Whenever possible cylinders should be stored in a vertical position (piston rod up). This will minimize corrosion due to possible condensation which could occur inside the cylinder. This will also minimize seal damage.

4.1.3 – Port protector plugs should be left in the cylinder until the time of installation.

4.1.4 – If a cylinder is stored full of hydraulic fluid, expansion of the fluid due to temperature changes must be considered. Installing a check valve with free flow out of the cylinder is one method.

4.1.5 – When cylinders are mounted on equipment that is stored outside for extended periods, exposed unpainted surfaces, e.g. piston rod, must be coated with a rust-inhibiting compound to prevent corrosion.

4.2 Cylinder Trouble Shooting

4.2.1 – External Leakage

4.2.1.1 – Rod seal leakage can generally be traced to worn or

damaged seals. Examine the piston rod for dents, gouges or score marks, and replace piston rod if surface is rough.

Rod seal leakage could also be traced to gland wear. If clearance is excessive, replace rod bushing and seal. Rod seal leakage can also be traced to seal deterioration. If seals are soft or gummy or brittle, check compatibility of seal material with lubricant used if air cylinder, or operating fluid if hydraulic cylinder. Replace with seal material, which is compatible with these fluids. If the seals are hard or have lost elasticity, it is usually due to exposure to temperatures in excess of 165°F. (+74°C). Shield the cylinder from the heat source to limit temperature to 350°F. (+177°C.) and replace with fluorocarbon seals.

4.2.1.2 – Cylinder body seal leak can generally be traced to loose tie rods. Torque the tie rods to manufacturer's recommendation for that bore size.

Excessive pressure can also result in cylinder body seal leak. Determine maximum pressure to rated limits. Replace seals and retorque tie rods as in paragraph above. Excessive pressure can also result in cylinder body seal leak. Determine if the pressure rating of the cylinder has been exceeded. If so, bring the operating pressure down to the rating of the cylinder and have the tie rods replaced.

Pinched or extruded cylinder body seal will also result in a leak. Replace cylinder body seal and retorque as in paragraph above.

Cylinder body seal leakage due to loss of radial squeeze which shows up in the form of flat spots or due to wear on the O.D. or I.D. – Either of these are symptoms of normal wear due to high cycle rate or length of service. Replace seals as per paragraph above.

4.2.2 – Internal Leakage

4.2.2.1 – Piston seal leak (by-pass) 1 to 3 cubic inches per minute leakage is considered normal for piston ring construction. Virtually no static leak with lipseal type seals on piston should be expected. Piston seal wear is a usual cause of piston seal leakage. Replace seals as required.

4.2.2.2 – With lipseal type piston seals excessive back pressure due to over-adjustment of speed control valves could be a direct cause of rapid seal wear. Contamination in a hydraulic system can result in a scored cylinder bore, resulting in rapid seal wear. In either case, replace piston seals as required.

4.2.2.3 – What appears to be piston seal leak, evidenced by the fact that the cylinder drifts, is not always traceable to the piston. To make sure, it is suggested that one side of the cylinder piston be pressurized and the fluid line at the opposite port be disconnected. Observe leakage. If none is evident, seek the cause of cylinder drift in other component parts in the circuit.

4.2.3 – Cylinder Fails to Move the Load

4.2.3.1 – Pneumatic or hydraulic pressure is too low. Check the pressure at the cylinder to make sure it is to circuit requirements.

4.2.3.2 – Piston Seal Leak – Operate the valve to cycle the cylinder and observe fluid flow at valve exhaust ports at end of cylinder stroke. Replace piston seals if flow is excessive.

4.2.3.3 – Cylinder is undersized for the load – Replace cylinder with one of a larger bore size.

4.3 Erratic or Chatter Operation

4.3.1 – Excessive friction at rod gland or piston bearing due to load misalignment – Correct cylinder-to-load alignment.

4.3.2 – Cylinder sized too close to load requirements – Reduce load or install larger cylinder.

4.3.3 – Erratic operation could be traced to the difference between static and kinetic friction. Install speed control valves to provide a back pressure to control the stroke.

4.4 Cylinder Modifications, Repairs, or Failed Component

Cylinders as shipped from the factory are not to be disassembled and or modified. If cylinders require modifications, these modifications must be done at company locations or by the Company's certified facilities. The Cylinder Division Engineering Department must be notified in the event of a mechanical fracture or permanent deformation of any cylinder component (excluding seals). This includes a broken piston rod, tie rod, mounting accessory or any other cylinder component. The notification should include all operation and application details. This information will be used to provide an engineered repair that will prevent recurrence of the failure.

It is allowed to disassemble cylinders for the purpose of replacing seals or seal assemblies. However, this work must be done by strictly following all the instructions provided with the seal kits.

The items described in this document and other documents and descriptions provided by Parker Hannifin Corporation, its subsidiaries and its authorized distributors ("Seller") are hereby offered for sale at prices to be established by Seller. This offer and its acceptance by any customer ("Buyer") shall be governed by all of the following Terms and Conditions. Buyer's order for any item described in its document, when communicated to Seller verbally, or in writing, shall constitute acceptance of this offer. All goods, services or work described will be referred to as "Products".

1. Terms. All sales of Products by Seller will be governed by, and are expressly conditioned upon Buyer's assent to, these Terms. These Terms are incorporated into any Quote provided by Seller to Buyer. Buyer's order for any Products whether communicated to Seller verbally, in writing, by electronic data interface or other electronic commerce, shall constitute acceptance of these Terms. Seller objects to any contrary or additional terms or conditions of Buyer. Reference in Seller's order acknowledgement to Buyer's purchase order or purchase order number shall in no way constitute an acceptance of any of Buyer's terms or conditions of purchase. Any Quote made by Seller to Buyer shall be considered a firm and definite offer and shall not be deemed to be otherwise despite any language on the face of the Quote. Seller reserves all rights to accept or reject any purported acceptance by Buyer to Seller's Quote if such purported acceptance attempts to vary the terms of the Quote. If Seller ships Products after Buyer issues an acceptance to the Quote, any additional or different terms proposed by Buyer will not become part of the parties' business relationship unless agreed to in a writing that is signed by an authorized representative of Seller, excluding email correspondence. If the transaction proceeds without such agreement on the part of Seller, the business relationship will be governed solely by these Terms and the specific terms in Seller's Quote.

2. Price; Payment. The Products set forth in the Quote are offered for sale at the prices indicated in the Quote. Unless otherwise specifically stated in the Quote, prices are valid for thirty (30) days and do not include any sales, use, or other taxes or duties. Seller reserves the right to modify prices for any reason and at any time by giving ten (10) days prior written notice. Unless otherwise specified by Seller, all prices are F.C.A. Seller's facility (INCOTERMS 2020). All sales are contingent upon credit approval and full payment for all purchases is due thirty (30) days from the date of invoice (or such date as may be specified in the Quote). Under any circumstances, Buyer may not withhold or suspend payment of any amounts due and payable as a deduction, set-off or recoupment of any amount, claim or dispute with Seller. Unpaid invoices beyond the specified payment date incur interest at the rate of 1.5% per month or the maximum allowable rate under applicable law. Seller reserves the right to require advance payment or provision of securities for first and subsequent deliveries if there is any doubt, in Seller's sole determination, regarding the Buyer's creditworthiness or for other business reasons. If the requested advance payment or securities are not provided to Seller's satisfaction, Seller reserves the right to suspend performance or reject the purchase order, in whole or in part, without prejudice to Seller's other rights or remedies, including the right to full compensation. Seller may revoke or shorten any payment periods previously granted in Seller's sole determination. The rights and remedies herein reserved to Seller are cumulative and in addition to any other or further rights and remedies available at law or in equity. No waiver by Seller of any breach by Buyer of any provision of these terms will constitute a waiver by Seller of any other breach of such provision.

3. Shipment; Delivery; Title and Risk of Loss. All delivery dates are approximate, and Seller is not responsible for damages or additional costs resulting from any delay. All deliveries are subject to our ability to procure materials from our suppliers. Regardless of the manner of shipment, delivery occurs and title and risk of loss or damage pass to Buyer, upon placement of the Products with the carrier at Seller's facility. Unless otherwise agreed prior to shipment and for domestic delivery locations only, Seller will select and arrange, at Buyer's sole expense, the carrier and means of delivery. When Seller selects and arranges the carrier and means of delivery, freight and insurance costs for shipment to the designated delivery location will be prepaid by Seller and added as a separate line item to the invoice. Buyer shall be responsible for any additional shipping charges incurred by Seller due to Buyer's acts or omissions. Buyer shall not return or repackage any Products without the prior written authorization from Seller, and any return shall be at the sole cost and expense of Buyer.

4. Warranty. The warranty for the Products is as follows: (i) Goods are warranted against defects in material or workmanship for a period of eighteen (18) months from the date of delivery or 2,000 hours of use, whichever occurs first; (ii) Services shall be performed in accordance with generally accepted practices and using the degree of care and skill that is ordinarily exercised and customary in the field to which the Services pertain and are warranted for a period of six (6) months from the date of completion of the Services; and (iii) Software is only warranted to perform in accordance with applicable specifications provided by Seller to Buyer for ninety (90) days from the date of delivery or, when downloaded by a Buyer or end-user, from the date of the initial download. All prices are based upon the exclusive limited warranty stated above, and upon the following disclaimer: **EXEMPTION CLAUSE; DISCLAIMER OF WARRANTY, CONDITIONS, REPRESENTATIONS: THIS WARRANTY IS THE SOLE AND ENTIRE WARRANTY, CONDITION, AND REPRESENTATION, PERTAINING TO PRODUCTS. SELLER DISCLAIMS ALL OTHER WARRANTIES, CONDITIONS, AND REPRESENTATIONS, WHETHER STATUTORY, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THOSE RELATING TO DESIGN, NONINFRINGEMENT, MERCHANTABILITY, AND FITNESS FOR A PARTICULAR PURPOSE. SELLER DOES NOT WARRANT THAT THE SOFTWARE IS ERROR-FREE OR FAULT-TOLERANT, OR THAT BUYER'S USE THEREOF WILL BE SECURE OR UNINTERRUPTED, UNLESS OTHERWISE AUTHORIZED IN WRITING BY SELLER, THE SOFTWARE SHALL NOT BE USED IN CONNECTION WITH HAZARDOUS OR HIGH-RISK ACTIVITIES OR ENVIRONMENTS. EXCEPT AS EXPRESSLY STATED HEREIN, ALL PRODUCTS ARE PROVIDED "AS IS".**

5. Claims; Commencement of Actions. Buyer shall promptly inspect all Products upon receipt. No claims for shortages will be allowed unless reported to Seller within ten (10) days of delivery. Buyer shall notify Seller of any alleged breach of warranty within thirty (30) days after the date the non-conformance is or should have been discovered by Buyer. Any claim or action against Seller based upon breach of contract or any other theory, including tort, negligence, or otherwise must be commenced within twelve (12) months from the date of the alleged breach or other alleged event, without regard to the date of discovery.

6. LIMITATION OF LIABILITY. IN THE EVENT OF A BREACH OF WARRANTY, SELLER WILL, AT ITS OPTION, REPAIR OR REPLACE THE NON-CONFORMING PRODUCTS, RE-PERFORM THE SERVICES, OR REFUND THE PURCHASE PRICE PAID WITHIN A REASONABLE PERIOD OF TIME. IN NO EVENT IS SELLER LIABLE FOR ANY SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES INCLUDING ANY LOSS OF REVENUE OR PROFITS, WHETHER BASED IN CONTRACT, TORT OR OTHER LEGAL THEORY. IN NO EVENT SHALL SELLER'S LIABILITY UNDER ANY CLAIM MADE BY BUYER EXCEED THE PURCHASE PRICE PAID FOR THE PRODUCTS.

7. Confidential Information. Buyer acknowledges and agrees that Confidential Information has been and will be received in confidence and will remain the property of Seller. Buyer further agrees that it will not use Seller's Confidential Information for any purpose other than for the benefit of Seller and shall return all such Confidential Information to Seller within thirty (30) days upon request.

8. Loss to Buyer's Property. Buyer's Property will be considered obsolete and may be destroyed by Seller after two (2) consecutive years have elapsed without Buyer ordering the Products manufactured using Buyer's Property. Also, Seller shall not be responsible for any loss or damage to Buyer's Property while it is in Seller's possession or control.

9. Special Tooling. Seller may impose a tooling charge for any Special Tooling. Special Tooling shall be and remain Seller's property. In no event will Buyer acquire any interest in the Special Tooling, even if such Special Tooling has been specially converted or adapted for manufacture of Goods for Buyer and notwithstanding any charges paid by Buyer. Unless otherwise agreed, Seller has the right to alter, discard or otherwise dispose of any Special Tooling or other property owned by Seller in its sole determination at any time.

10. Security Interest. To secure payment of all sums due from Buyer, Seller retains a security interest in all Products delivered to Buyer, and Buyer's acceptance of these Terms is deemed to be a Security Agreement under the Uniform Commercial Code. Buyer authorizes Seller as its attorney to execute and file on Buyer's behalf all documents Seller deems necessary to perfect Seller's security interest.

11. User Responsibility. Buyer, through its own analysis and testing, is solely responsible for making the final selection of the Products and assuring that all performance, endurance, maintenance, safety and warning requirements of the application of the Products are met. Buyer must analyze all aspects of the application and follow applicable industry standards, specifications, and any technical information provided with the Quote or the Products, such as Seller's instructions, guides and specifications. If Seller provides options of or for Products based upon data or specifications provided by Buyer, Buyer is responsible for determining that such data and specifications are suitable and sufficient for all applications and reasonably foreseeable uses of the Products. In the event Buyer is not the end-user of the Products, Buyer will ensure such end-user complies with this paragraph.

12. Use of Products, Indemnity by Buyer. Buyer shall comply with all instructions, guides and specifications provided by Seller with the Quote or the Products. If Buyer uses or resells the Products in any way prohibited by Seller's instructions, guides or specifications, or Buyer otherwise fails to comply with Seller's instructions, guides and specifications, Buyer acknowledges that any such use, resale, or non-compliance is at Buyer's sole risk. Further, Buyer shall indemnify, defend, and hold Seller harmless from any losses, claims, liabilities, damages, lawsuits, judgments and costs (including attorney fees and defense costs), whether for personal injury, property damage, intellectual property infringement or any other claim, arising out of or in connection with: (a) improper selection, design, specification, application, or any misuse of Products; (b) any act or omission, negligent or otherwise, of Buyer; (c) Seller's use of Buyer's Property; (d)

damage to the Products from an external cause, repair or attempted repair by anyone other than Seller, failure to follow instructions, guides and specifications provided by Seller, use with goods not provided by Seller, or opening, modifying, deconstructing, tampering with or repackaging the Products; or (e) Buyer's failure to comply with these Terms, including any legal or administrative proceedings, collection efforts, or other actions arising from or relating to such failure to comply. Seller shall not indemnify Buyer under any circumstance except as otherwise provided in these Terms.

13. Cancellations and Changes. Buyer may not cancel or modify, including but not limited to movement of delivery dates for the Products, any order for any reason except with Seller's written consent and upon terms that will indemnify, defend and hold Seller harmless against all direct, incidental and consequential loss or damage and any additional expense. Seller, at any time, may change features, specifications, designs and availability of Products.

14. Assignment. Buyer may not assign its rights or obligations without the prior written consent of Seller.

15. Force Majeure. Seller is not liable for delay or failure to perform any of its obligations by reason of any events or circumstances beyond its reasonable control. Such circumstances include without limitation: accidents, labor disputes or stoppages, government acts or orders, acts of nature, pandemics, epidemics, other widespread illness, or public health emergency, cyber related disruptions, cyber-attacks, ransomware sabotage, delays or failures in delivery from carriers or suppliers, shortages of materials, sudden increases in the price of raw material or components, shutdowns or slowdowns affecting the supply of raw materials or components, or the transportation thereof, oil shortages or oil price increases, energy crisis, energy or fuel interruption, war (whether declared or not) or the serious threat of same, riots, rebellions, acts of terrorism, embargoes, fire or any reason whether similar to the foregoing or otherwise. Seller will resume performance as soon as practicable after the event of force majeure has been removed. All delivery dates affected by an event of force majeure shall be tolled for the duration of such event of force majeure and rescheduled for mutually agreed dates as soon as practicable after the event of force majeure ceases to exist. The right to allocate capacity is in the Seller's sole discretion. An event of force majeure shall not include financial distress, insolvency, bankruptcy, or other similar conditions affecting one of the parties, affiliates and/or sub-contractors. An event of force majeure in the meaning of these Terms means any circumstances beyond Seller's control that permanently or temporarily hinders performance, even where that circumstance was already foreseen. Buyer shall not be entitled to cancel any orders following its claim of an event of force majeure.

16. Waiver and Severability. Failure to enforce any provision of these Terms will not invalidate that provision; nor will any such failure prejudice either party's right to enforce that provision in the future. Invalidation of any provision of these Terms shall not invalidate any other provision herein and, the remaining provisions will remain in full force and effect.

17. Duration. Unless otherwise stated in the Quote, any agreement governed by or arising from these Terms shall: (a) be for an initial duration of one (1) year; and (b) shall automatically renew for successive one-year terms unless terminated by Buyer with at least 180-days written notice to Seller or if Seller terminates the agreement pursuant to Section 19 of these Terms.

18. Termination. Seller may, without liability to Buyer, terminate any agreement governed by or arising from these Terms for any reason and at any time by giving Buyer thirty (30) days prior written notice. Seller may immediately terminate, in writing, if Buyer: (a) breaches any provision of these Terms, (b) becomes or is deemed insolvent, (c) appoints or has appointed a trustee, receiver or custodian for all or any part of Buyer's property, (d) files a petition for relief in bankruptcy on its own behalf, or one is filed against Buyer by a third party, (e) makes an assignment for the benefit of creditors; or (f) dissolves its business or liquidates all or a majority of its assets.

19. Ownership of Rights. Buyer agrees that (a) Seller (and/or its affiliates) owns or is the valid licensee of Seller's IP and (b) the furnishing of information, related documents or other materials by Seller to Buyer does not grant or transfer any ownership interest or license in or to Seller's IP to Buyer, unless expressly agreed in writing. Without limiting the foregoing, Seller retains ownership of all Software supplied to Buyer. In no event shall Buyer obtain any greater right in and to the Software than a right in a license limited to the use thereof and subject to compliance with any other terms provided with the Software. Buyer further agrees that it will not, directly or through intermediaries, reverse engineer, decompile, or disassemble any Software (including firmware) comprising or contained within a Product, except and only to the extent that such activity may be expressly permitted, either by applicable law or, in the case of open source software, the applicable open source license.

20. Indemnity for Infringement of Intellectual Property Rights. Seller is not liable for infringement of any Intellectual Property Rights except as provided in this Section. Seller will defend at its expense and will pay the cost of any settlement or damages awarded in an action brought against Buyer based on a third-party claim that one or more of the Products infringes the Intellectual Property Rights of a third party in the country of delivery of the Products by Seller to Buyer. Seller's obligation to defend and indemnify Buyer is contingent on Buyer notifying Seller within ten (10) days after Buyer becomes aware of any such claim, and Seller having sole control over the defense of the claim including all negotiations for settlement or compromise. If one or more Products is subject to such a claim, Seller may, at its sole expense and option, procure for Buyer the right to continue using the Products, replace or modify the Products to render them non-infringing, or offer to accept return of the Products and refund the purchase price less a reasonable allowance for depreciation. Seller has no obligation or liability for any claim of infringement: (i) arising from information provided by Buyer (including Seller's use of Buyer's Property); or (ii) directed to any Products for which the designs are specified in whole or part by Buyer; or (iii) resulting from the modification, combination or use in a system of any Products. The foregoing provisions of this Section constitute Seller's sole and exclusive liability and Buyer's sole and exclusive remedy for claims of infringement of Intellectual Property Rights.

21. Governing Law. These Terms, the terms of any Quote, and the sale and delivery of all Products are deemed to have taken place in, and shall be governed and construed in accordance with, the laws of the State of Ohio, as applicable to contracts executed and wholly performed therein and without regard to conflicts of laws principles. Buyer irrevocably agrees and consents to the exclusive jurisdiction and venue of the courts of Cuyahoga County, Ohio with respect to any dispute, controversy or claim arising out of or relating to the sale and delivery of the Products.

22. Entire Agreement. These Terms, along with the terms set forth in the Quote, forms the entire agreement between the Buyer and Seller and constitutes the final, complete and exclusive expression of the terms of sale and purchase. In the event of a conflict between any term set forth in the Quote and these Terms, the terms set forth in the Quote shall prevail. All prior or contemporaneous written or oral agreements or negotiations with respect to the subject matter shall have no effect. No modification to these Terms will be binding on Seller unless agreed to in a writing that is signed by an authorized representative of Seller, excluding email correspondence, "clickwrap" or other purported electronic assent to different or additional terms. Sections 2-25 of these Terms shall survive termination or cancellation of any agreement governed by or arising from these Terms.

23. No 'Wrap' Agreements/No Authority to Bind. Seller's clicking any buttons or any similar action, such as clicking "I Agree" or "Confirm," to utilize Buyer's software or webpage for the placement of orders, is NOT an agreement to Buyer's Terms and Conditions. NO EMPLOYEE, AGENT OR REPRESENTATIVE OF SELLER HAS THE AUTHORITY TO BIND SELLER BY THE ACT OF CLICKING ANY BUTTON OR SIMILAR ACTION ON BUYER'S WEBSITE OR PORTAL.

24. Compliance with Laws. Buyer agrees to comply with all applicable laws, regulations, and industry and professional standards, including those of the United States of America, and the country or countries in which Buyer may operate, including without limitation the U.S. Foreign Corrupt Practices Act ("FCPA"), the U.S. Anti-Kickback Act ("Anti-Kickback Act"), U.S. and E.U. export control and sanctions laws ("Export Laws"), the U.S. Food Drug and Cosmetic Act ("FDCA"), and the rules and regulations promulgated by the U.S. Food and Drug Administration ("FDA"), each as currently amended. Buyer agrees to indemnify, defend, and hold harmless Seller from the consequences of any violation of such laws, regulations and standards by Buyer, its employees or agents. Buyer represents that it is familiar with all applicable provisions of the FCPA, the Anti-Kickback Act, Export Laws, the FDCA and the FDA and certifies that Buyer will adhere to the requirements thereof and not take any action that would make Seller violate such requirements. Buyer represents and agrees that Buyer will not make any payment or give anything of value, directly or indirectly, to any governmental official, foreign political party or official thereof, candidate for foreign political office, or commercial entity or person, for any improper purpose, including the purpose of influencing such person to purchase Products or otherwise benefit the business of Seller. Buyer further represents and agrees that it will not receive, use, service, transfer or ship any Products from Seller in a manner or for a purpose that violates Export Laws or would cause Seller to be in violation of Export Laws. Buyer agrees to promptly and reliably provide Seller all requested information or documents, including end-user statements and other written assurances, concerning Buyer's ongoing compliance with Export Law. 9/22





Parker's Motion & Control Technologies

At Parker, we're guided by a relentless drive to help our customers become more productive and achieve higher levels of profitability by engineering the best systems for their requirements. It means looking at customer applications from many angles to find new ways to create value. Whatever the motion and control technology need, Parker has the experience, breadth of product and global reach to consistently deliver. No company knows more about motion and control technology than Parker. For further info call 1 800 C-Parker (1 800 272 7537)



Aerospace

Key Markets

- Aftermarket services
- Commercial transports
- Engines
- General & business aviation
- Helicopters
- Launch vehicles
- Military aircraft
- Missiles
- Power generation
- Regional transports
- Unmanned aerial vehicles

Key Products

- Control systems & actuation products
- Engine systems & components
- Fluid conveyance systems & components
- Fluid metering, delivery & atomization devices
- Fuel systems & components
- Fuel tank inerting systems
- Hydraulic systems & components
- Thermal management
- Wheels & brakes



Climate Control

Key Markets

- Agriculture
- Air conditioning
- Construction Machinery
- Food & beverage
- Industrial machinery
- Life sciences
- Oil & gas
- Precision cooling
- Process
- Refrigeration
- Transportation

Key Products

- Accumulators
- Advanced actuators
- CO₂ controls
- Electronic controllers
- Filter driers
- Hand shut-off valves
- Heat exchangers
- Hose & fittings
- Pressure regulating valves
- Refrigerant distributors
- Safety relief valves
- Smart pumps
- Solenoid valves
- Thermostatic expansion valves



Electromechanical

Key Markets

- Aerospace
- Factory automation
- Life science & medical
- Machine tools
- Packaging machinery
- Paper machinery
- Plastics machinery & converting
- Primary metals
- Semiconductor & electronics
- Textile
- Wire & cable

Key Products

- AC/DC drives & systems
- Electric actuators, gantry robots & slides
- Electrohydraulic actuation systems
- Electromechanical actuation systems
- Human machine interface
- Linear motors
- Stepper motors, servo motors, drives & controls
- Structural extrusions



Filtration

Key Markets

- Aerospace
- Food & beverage
- Industrial plant & equipment
- Life sciences
- Marine
- Mobile equipment
- Oil & gas
- Power generation & renewable energy
- Process
- Transportation
- Water Purification

Key Products

- Analytical gas generators
- Compressed air filters & dryers
- Engine air, coolant, fuel & oil filtration systems
- Fluid condition monitoring systems
- Hydraulic & lubrication filters
- Hydrogen, nitrogen & zero air generators
- Instrumentation filters
- Membrane & fiber filters
- Microfiltration
- Sterile air filtration
- Water desalination & purification filters & systems



Fluid & Gas Handling

Key Markets

- Aerial lift
- Agriculture
- Bulk chemical handling
- Construction machinery
- Food & beverage
- Fuel & gas delivery
- Industrial machinery
- Life sciences
- Marine
- Mining
- Mobile
- Oil & gas
- Renewable energy
- Transportation

Key Products

- Check valves
- Connectors for low pressure fluid conveyance
- Deep sea umbilicals
- Diagnostic equipment
- Hose couplings
- Industrial hose
- Mooring systems & power cables
- PTFE hose & tubing
- Quick couplings
- Rubber & thermoplastic hose
- Tube fittings & adapters
- Tubing & plastic fittings



Hydraulics

Key Markets

- Aerial lift
- Agriculture
- Alternative energy
- Construction machinery
- Forestry
- Industrial machinery
- Machine tools
- Marine
- Material handling
- Mining
- Oil & gas
- Power generation
- Refuse vehicles
- Renewable energy
- Truck hydraulics
- Turf equipment

Key Products

- Accumulators
- Cartridge valves
- Electrohydraulic actuators
- Human machine interfaces
- Hybrid drives
- Hydraulic cylinders
- Hydraulic motors & pumps
- Hydraulic systems
- Hydraulic valves & controls
- Hydrostatic steering
- Integrated hydraulic circuits
- Power take-offs
- Power units
- Rotary actuators
- Sensors



Pneumatics

Key Markets

- Aerospace
- Conveyor & material handling
- Factory automation
- Life science & medical
- Machine tools
- Packaging machinery
- Transportation & automotive

Key Products

- Air preparation
- Brass fittings & valves
- Manifolds
- Pneumatic accessories
- Pneumatic actuators & grippers
- Pneumatic valves & controls
- Quick disconnects
- Rotary actuators
- Rubber & thermoplastic hose & couplings
- Structural extrusions
- Thermoplastic tubing & fittings
- Vacuum generators, cups & sensors



Process Control

Key Markets

- Alternative fuels
- Biopharmaceuticals
- Chemical & refining
- Food & beverage
- Marine & shipbuilding
- Medical & dental
- Microelectronics
- Nuclear Power
- Offshore oil exploration
- Oil & gas
- Pharmaceuticals
- Power generation
- Pulp & paper
- Steel
- Water/wastewater

Key Products

- Analytical Instruments
- Analytical sample conditioning products & systems
- Chemical injection fittings & valves
- Fluoropolymer chemical delivery fittings, valves & pumps
- High purity gas delivery fittings, valves, regulators & digital flow controllers
- Industrial mass flow meters/ controllers
- Permanent no-weld tube fittings
- Precision industrial regulators & flow controllers
- Process control double block & bleeds
- Process control fittings, valves, regulators & manifold valves



Sealing & Shielding

Key Markets

- Aerospace
- Chemical processing
- Consumer
- Fluid power
- General industrial
- Information technology
- Life sciences
- Microelectronics
- Military
- Oil & gas
- Power generation
- Renewable energy
- Telecommunications
- Transportation

Key Products

- Dynamic seals
- Elastomeric o-rings
- Electro-medical instrument design & assembly
- EMI shielding
- Extruded & precision-cut, fabricated elastomeric seals
- High temperature metal seals
- Homogeneous & inserted elastomeric shapes
- Medical device fabrication & assembly
- Metal & plastic retained composite seals
- Shielded optical windows
- Silicone tubing & extrusions
- Thermal management
- Vibration dampening

ENGINEERING YOUR SUCCESS.



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