Operation and Installation Manual

Models covered by this manual:

EHPU (Electro-Hydraulic Power Unit)
EHSU (Electro-Hydraulic Steering Unit)

Revision 1.1 (working copy)

HYDRAPULSE® EHPU

HYDRAPULSE® EHSU

Reading this Document

This document is to be used as a reference tool to aid in design and integration of the Hydrapulse® EHPU (Electro-hydraulic Power Unit) and Hydrapulse® EHSU (Electro-hydraulic steering unit). The user of this document should have a basic understanding of mechanical, electrical, and hydraulic equipment. Read this document before beginning the installation of the Hydrapulse®.
Sections marked with a symbol in the left margin must be read and understood by everyone designing, installing, changing, or maintaining a Hydrapulse® Unit. The different symbols used in this document are listed below.

WARNING

Sections labeled WARNING with a symbol in the left margin indicate a potentially hazardous situation may exist. This is of special importance and should be understood by everyone using the Hydrapulse®. Failure to comply with the recommendations can cause unintentional, and unexpected behavior of the control system. This can potentially cause death, serious injury or property damage.

NOTICE

Sections labeled NOTICE with a symbol in the left margin indicate there is important information about the Hydrapulse®. Ignoring this could result in less than ideal operating parameters or damage to the product.

Precautions

Work to the hydraulic system or electrical system may only be done by a trained professional that understands the complications and dangers of such systems. The Hydrapulse® EHPU & EHSU units are designed to control high power hydraulics. This industry is inherently dangerous. Care must be taken when designing, testing, maintaining, and operating such systems. Failure to do so may result in property damage, personal injury, or death.

WARNING

FAILURE OR IMPROPER SELECTION OR IMPROPER USE OF THE PRODUCTS AND/OR SYSTEMS DESCRIBED HEREIN OR RELATED ITEMS CAN CAUSE DEATH, PERSONAL INJURY AND PROPERTY DAMAGE.

This document and other information from Terzo Power Systems, its subsidiaries and authorized distributors provide product and/or system options for further investigation by users having technical expertise. It is important that all aspects of the application be analyzed, including consequences of any failure, and review the information concerning the product or system in the current product catalogue. Due to the variety of operating conditions and applications for these products or systems, the user, through his or her own analysis and testing, is solely responsible for making the final selection of the products and systems and assuring that all performance, safety and warning requirements of the application are met. The products described herein, including without limitation, product features, specifications, designs, availability and pricing, are subject to change by Terzo Power Systems, LLC and its subsidiaries at any time without notice.

WARNING

This product can expose you to chemicals including lead, which is known to the State of California to cause cancer. For more information, visit www.P65Warnings.ca.gov.

WARNING

High Pressure Oil can cause severe injury or death! Disconnect power and relieve pressure prior to servicing the hydraulic equipment.
DO NOT USE HANDS OR FINGERS to find leaks. Fluid under high pressure can be injected into skin causing extreme injury and serious infection. Use a piece of cardboard to locate leaks. Small high-pressure jets may be hard to see.
Spilled hydraulic oil can cause burns, other accidents due to slippery conditions and can also harm the environment. Take care of all spilled oil and handle it according to your safety and environmental regulations. Never disassemble hydraulic components when the hydraulic oil is hot.

Document Library

All documents, manuals, videos, and supporting information can be found online on our Resource Center page https://terzopower.com/resource-center/

Links to specific documents are found in the table below.

Description	Filename / Link
Operations and Installation Manual	hydrapulse_operating_installation_manual_vxx.pdf
Latest firmware files	terzopower.com/hydrapulse-firmware/
2D & 3D CAD files	terzopower.com/hydrapulse-cad/
Installation and operation videos	terzopower.com/video-library/
Case Studies	terzopower.com/case-studies/
Datasheets	terzopower.com/hydrapulse-datasheets/
Faq's	terzopower.com/hydrapulse-faqs/
Hydrapulse® Solution Center	terzopower.com/solutions-center/

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1 EHPU Model

1.1 Product Overview

The Hydrapulse® EHPU unit is a hydraulic power unit (HPU) with an integrated motor, drive and controller specifically designed for advanced hydraulic control.

The Hydrapulse® family comes in three frame sizes: 100, 200, and 300.

The workings of each frame sizes are the same, so while this manual may only include images and figures depicting one size, all instructions apply to all three frame sizes.

The device is divided into two primary components: the Pump Side and the Drive Side as shown below in Figure 1.1. These two primary components are overviewed in the following sections.

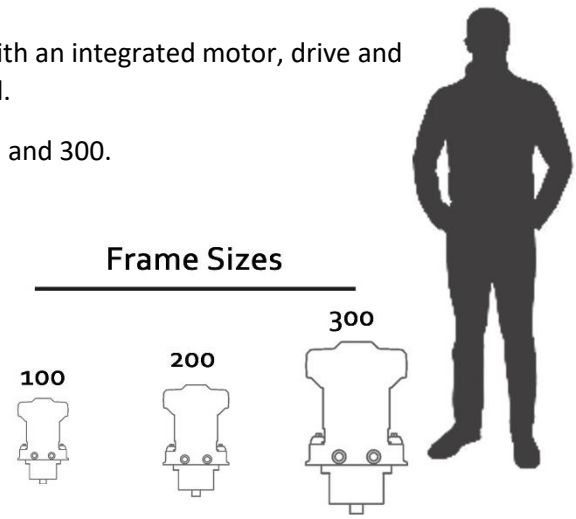
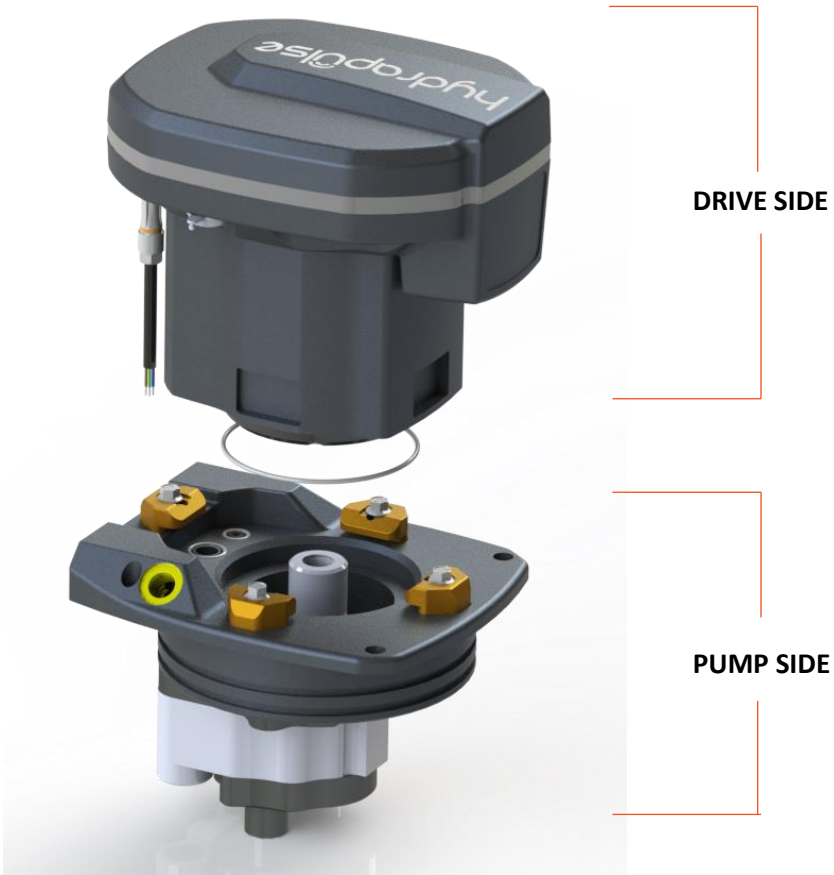


Figure 1.1: Hydrapulse® Drive Side (above) and Pump Side assembly (below)



1.1.1 Pump Side

The Pump Side of the device includes the Hydrapulse® base, hydraulic pump, and all hydraulic components. Any properly sized hydraulic pump may be used with the appropriate output shaft and mounting flange. An additional customer supplied manifold may be required to achieve the desired functionality. Alternatively, Hydrapulse® specific integrated pumps may be used to eliminate the need for external manifolds and valving. These are referenced later in this document.

The base includes ports to connect directly to a hydraulic load, and some units include additional ports that may be used to add other hydraulic components such as filers and coolers into the Hydrapulse® circuit.

1.1.2 Drive Side

The Drive Side of the device includes the permanent magnet (PM) motor, motor drive circuitry, an array of sensors, and the control circuitry and logic. The Drive Side may be completely disconnected from the Pump Side to troubleshoot either assembly or perform maintenance.

1.2 Product Options and Accessories

The Hydrapulse® product family has several options and accessories depending on your application. Please refer to the datasheets found at www.terzopower.com for a complete list. For pricing and availability, contact our sales team or email at sales@terzopower.com.

1.3 Pump Side Installation

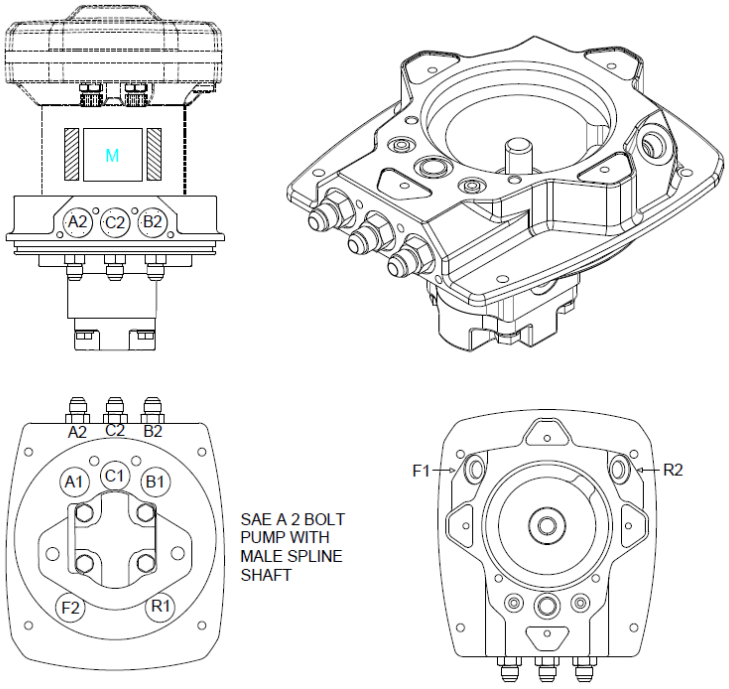
1.3.1 Hydraulic Fittings

Figure 1.2 shows the port options for the two different bases available in Beta.

Note – when ordering as a Beta user, Gen 1 Beta base will be assumed unless Gen 2 Beta base is specifically requested.

Figure 1.2: Hydrapulse® port options

(a) Gen 1 Beta base



(b) Gen 2 Beta base with optional filter/cooler ports

Gen 1 Beta Base

All hydraulic ports are SAE O-ring boss (ORB) -06 ports. Both the A and B ports on the device have two options for connecting fittings. One pair of ports lies flat coming out the side of the base, and the other pair is offset 45 degrees on the sides. The user is given flexibility to install pressure gauges on unused ports. It is critical that all unused ports are plugged to prevent leakage during operation.

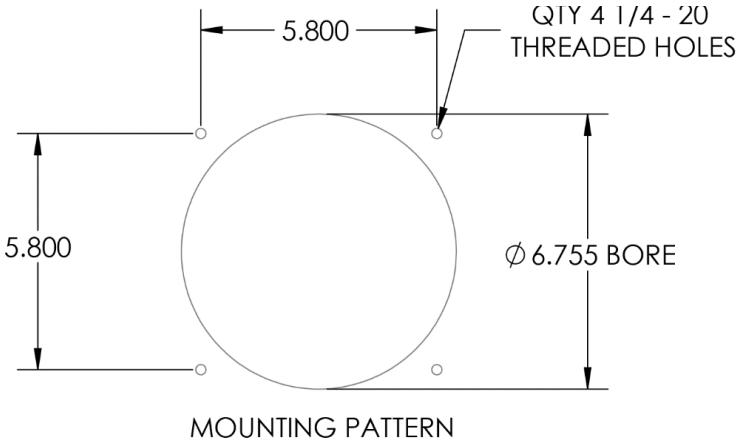
Gen 2 Beta Base

All hydraulic ports are SAE O-ring boss (ORB) -06 ports. All ports with the same prefix (such as A1 and A2) are connected internally. The Gen 2 base has additional ports that allow the user to connect an external return oil filter or cooler to the unit.

1.3.2 Base Mounting

The Pump Side should be installed first to a reservoir with 1/4 -20 socket head cap screws, and then fitted with any hydraulic hoses or gauges as required by the application.

Figure 1.3: Base mounting dimensions



1.3.3 Pump installation

The Hydrapulse can be used with any pump that has the matching SAE flange mount and drive shaft. The HP-015-001 Hydrapulse is compatible with all SAE A 2 bolt flange mount pumps with a male SAE A spline shaft. The user may supply their own pump or use an integrated pump available from Hydrapulse. The integrated pump should be installed onto the base mount as shown below in Figure 1.4, with extra care being taken to install O-rings into the recesses of the three ORB ports covered by the pump. An optional O-ring may be installed around the SAE A pilot boss to prevent oil from leaking over the pump during operation.

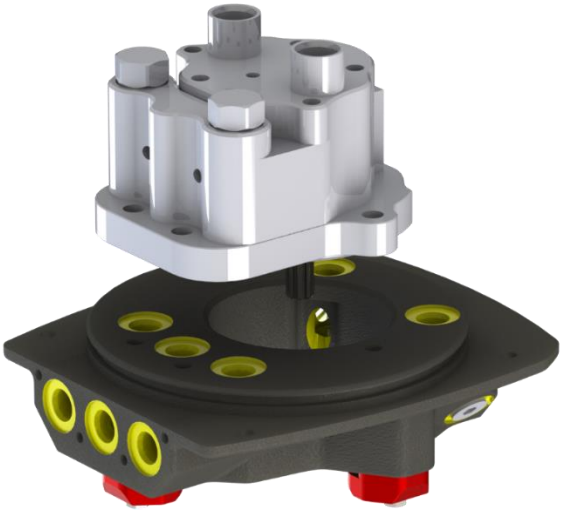


Figure 1.4: Integrated Pump Assembly

1.3.4 Reservoir Installation

The Pump Side assembly can be fitted to a reservoir in a variety of ways. The user may provide their own reservoir and mount the Hydrapulse with either a radial O-ring seal, or by using the base gasket offered by Hydrapulse. The base gasket can be seen below in Figure 1.5.

Figure 1.5 Base Gasket

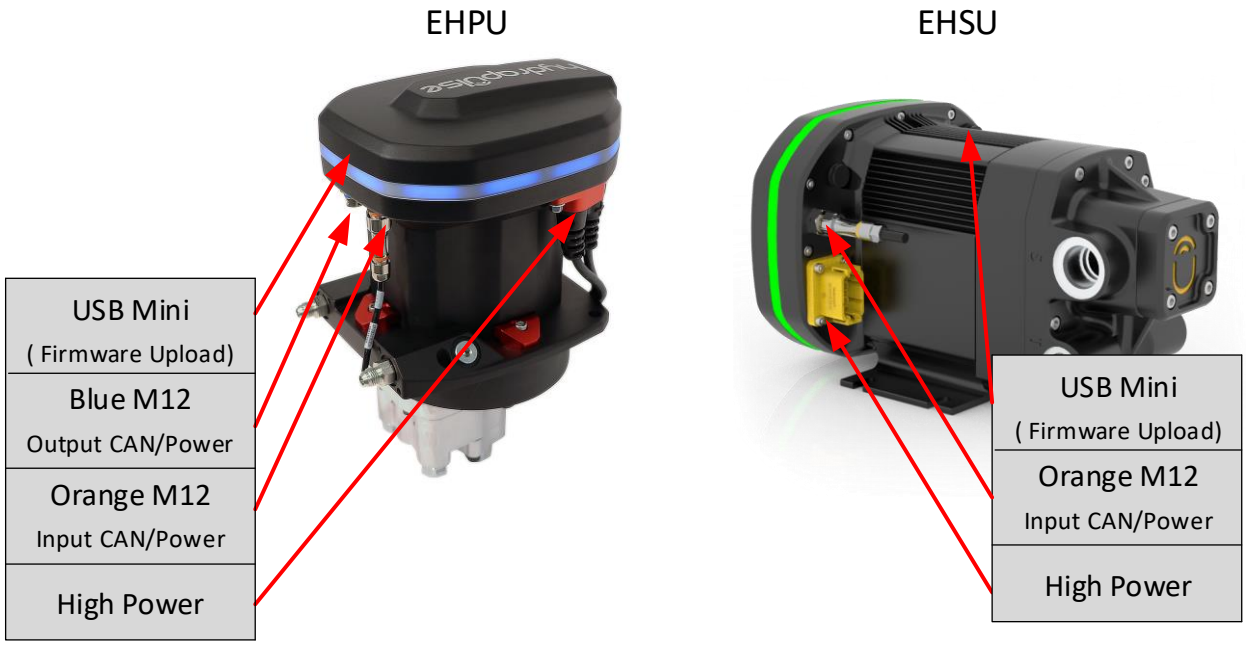
A reservoir provided by Hydrapulse is also available for purchase in several lengths. The reservoir shown below in Figure 1.6 packages the integrated pump while maintaining the same small footprint of the Hydrapulse. The reservoir mates to the Hydrapulse base with the radial O-ring seal described above and is secured with four ¼-20 socket head cap screws.

Figure 1.6: Hydrapulse Reservoir Option

1.4 Drive Side

1.4.1 Connections

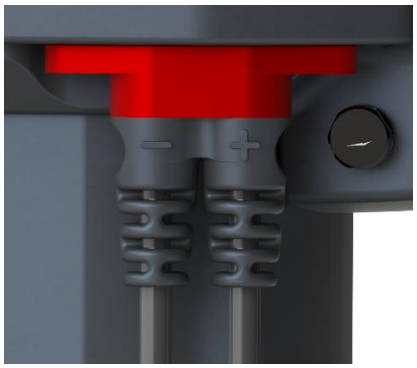
There are four connections on the Hydrapulse® EHPU model: motor power, main communication, auxiliary communication, and USB. (Note: there are only three connections on the EHSU model) The following sections detail locations, pinouts, and functionality for these connections.



Connector Locations

Figure 1.7 shows the locations for all four connections on the device. The motor power and USB connections are located on the right side, while the main and auxiliary communication connections are located on the front of the device.

Figure 1.7: Device connection locations



(a) Motor power connection

(b) USB connection

(c) Main communication connection

(c) Auxiliary communication connection

CAN Description

The device uses the J1939 communication protocol over the CAN physical layer. For more information regarding the CAN physical layer, refer to SAE J1939 documentation.

For more information on J1939 implementation, refer to Chapter 5.

Safe Torque Off (E-Stops)

The two E-Stop signals in the communication cable must be wired to normally closed e-stop switches that connect them to Vcc. When either Estop is open, the motor drive circuitry is disabled at a hardware level.

NOTICE

Two E-stop signals are provided to give flexibility for the user to have two separate and independent e-stop switches, but should the user wish to only operate a single e-stop switch then the other signal may be tied high to Vcc. It is not recommended to bypass both E-Stop signals in this way.

1.5 Installing Drive Side to Pump Side

After installation of the Pump Side, the provided O-rings should be placed in the O-ring grooves and the larger O-ring should be installed around the boss on the underside of the Drive Side. An exploded view of the assembly process can be seen below in Figure 1.8.

The Drive Side should then be mated to the Pump Side, making sure that the spline coupling aligns with the spline shaft. The Drive Side should then be secured with the four toe clamps provided with the Pump Side assembly. Fasteners may be installed with a thread locker to prevent loosening due to vibration. With the Drive Side securely fastened, the communications cable and power cables may be installed as described in Chapter 3.

For more detailed instructions on mounting both the pump side and drive side of the Hydrapulse, refer to the media center on the Hydrapulse website. https://terzopower.com/resource-center/

Figure 1.8: Mating Drive Side to Pump Side

WARNING

Failure to properly install sealing o-rings can result in leaks in the high-pressure hydraulics. High pressure leaks present serious hazards and only trained personnel should disable or assemble the Hydrapulse® units.

1.6 Dimensions

Figure 1.9: Gen 1 Overall Dimensions

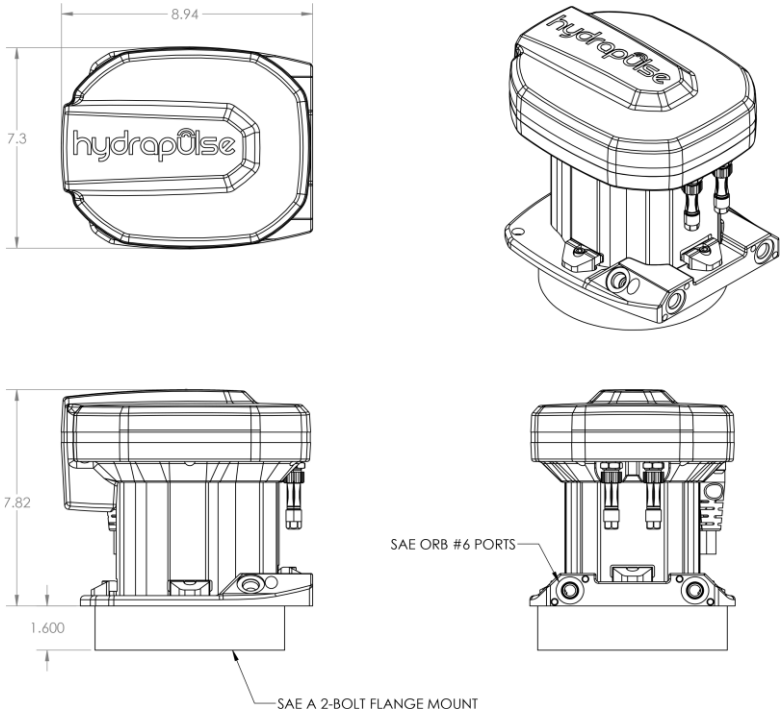
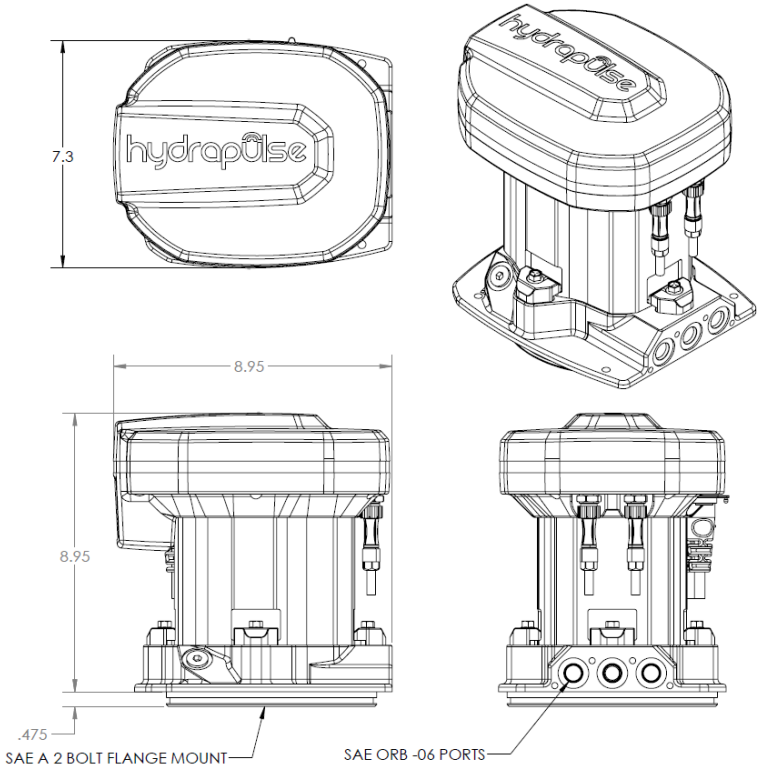


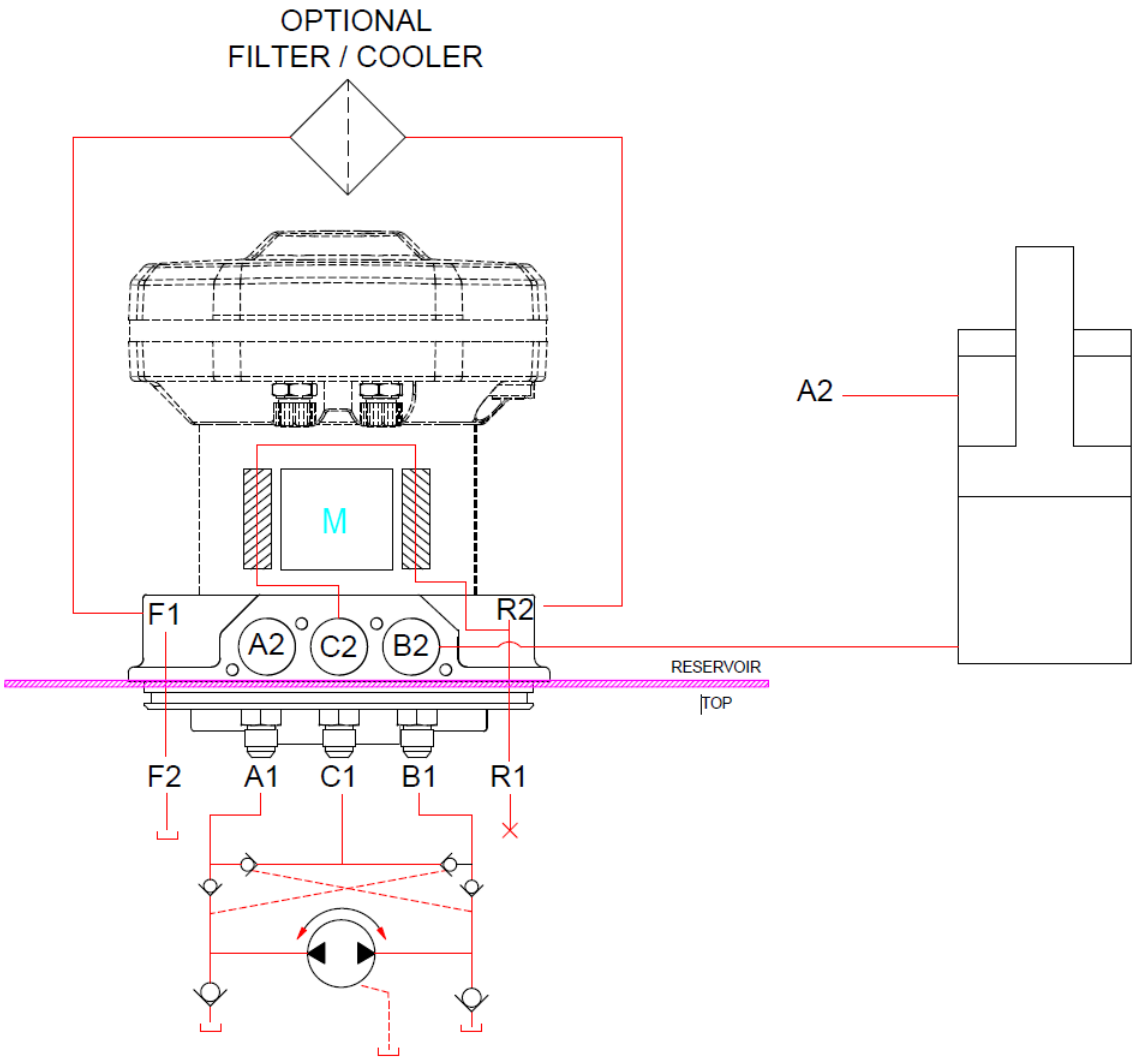
Figure 1.10: Gen 2 Overall Dimensions



1.7 Hydraulic Schematic

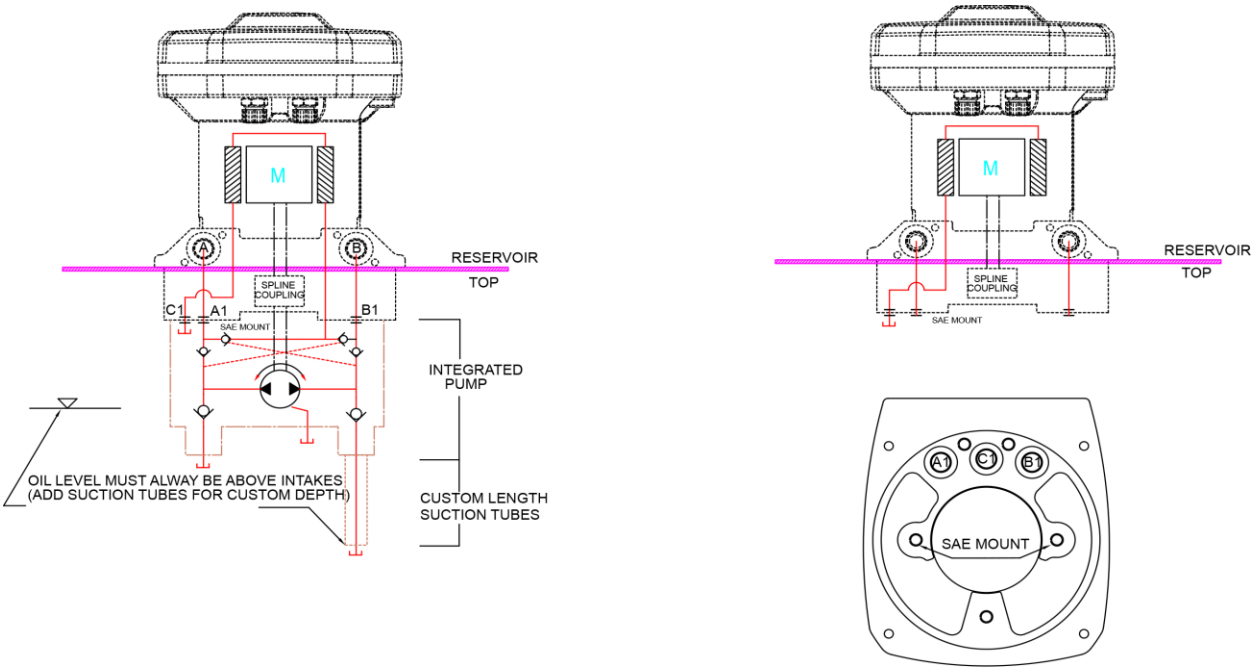
The Hydrapulse should be integrated into the following hydraulic schematic or similar. The user has the option of providing a pump for use with the Hydrapulse or using one of the standard integrated pumps available from Hydrapulse. The schematic below in Figure allows for the Hydrapulse to control the direction and speed of a cylinder by controlling the speed and direction of the pump. The return oil is redirected to port C1 in order to cool the electric motor of the Hydrapulse. After cooling the motor, the oil is forced to R1 and R2. The user is given the option to plug either R1 or R2 to force fluid back into the reservoir or out to an external filter or cooler as shown below. In the gen 1 base, after cooling the motor the oil flows over the pump and drains into the reservoir. It is critical that all unused ports are plugged to prevent leakage during operation.

Figure 1.11: Hydraulic Schematic Example



Hydrapulse integrated pumps include the above hydraulic circuit to eliminate the need for an external manifold, as can be seen below in Figure 1.12.

Figure 1.12: Integrated Pump Circuit



2 EHSU Model

2.1 Product Overview

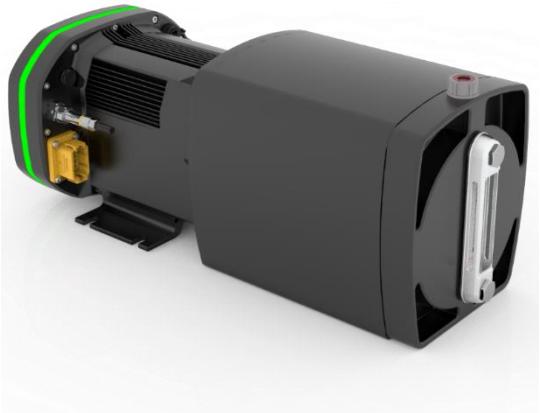
The Hydrapulse® EHSU unit is an electro-hydraulic steering unit (EHSU) with an integrated motor, drive and controller specifically designed for steering assist and e-steering applications on mobile vehicles including medium and heavy-duty trucks, buses, transit vehicles, airport and port equipment, and heavy-duty off-highway vehicles.

The EHSU comes in two frame sizes: 100 and 200.

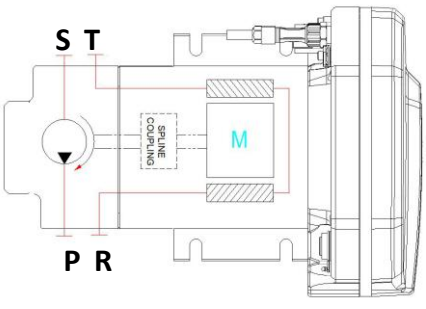
These two frames are based on our 75mm o.d. (frame size 100) and 140mm o.d. (frame size 200) motors. Both frame sizes use the same pump gearsets and can provide flowrates up to 15gpm. Pressure, flowrate, and available power requirements will determine what which EHSU model should be selected. More information on model sizing and performance, please refer to our EHSU datasheet located at https://terzopower.com/hydrapulse-datasheets/

There are two options for the EHSU, one is an integrated reservoir and one is a coolant pump. The coolant pump option is for applications where only pressure and return lines are available and an integrated reservoir is usually required with this option. For custom applications please contact our engineering department.

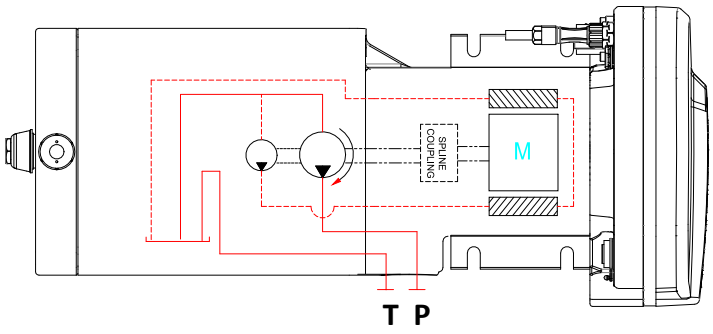
EHSU 2.5kW model



EHSU 2.5kW model with integrated reservoir (“R” option)



EHSU-2.5U MODEL

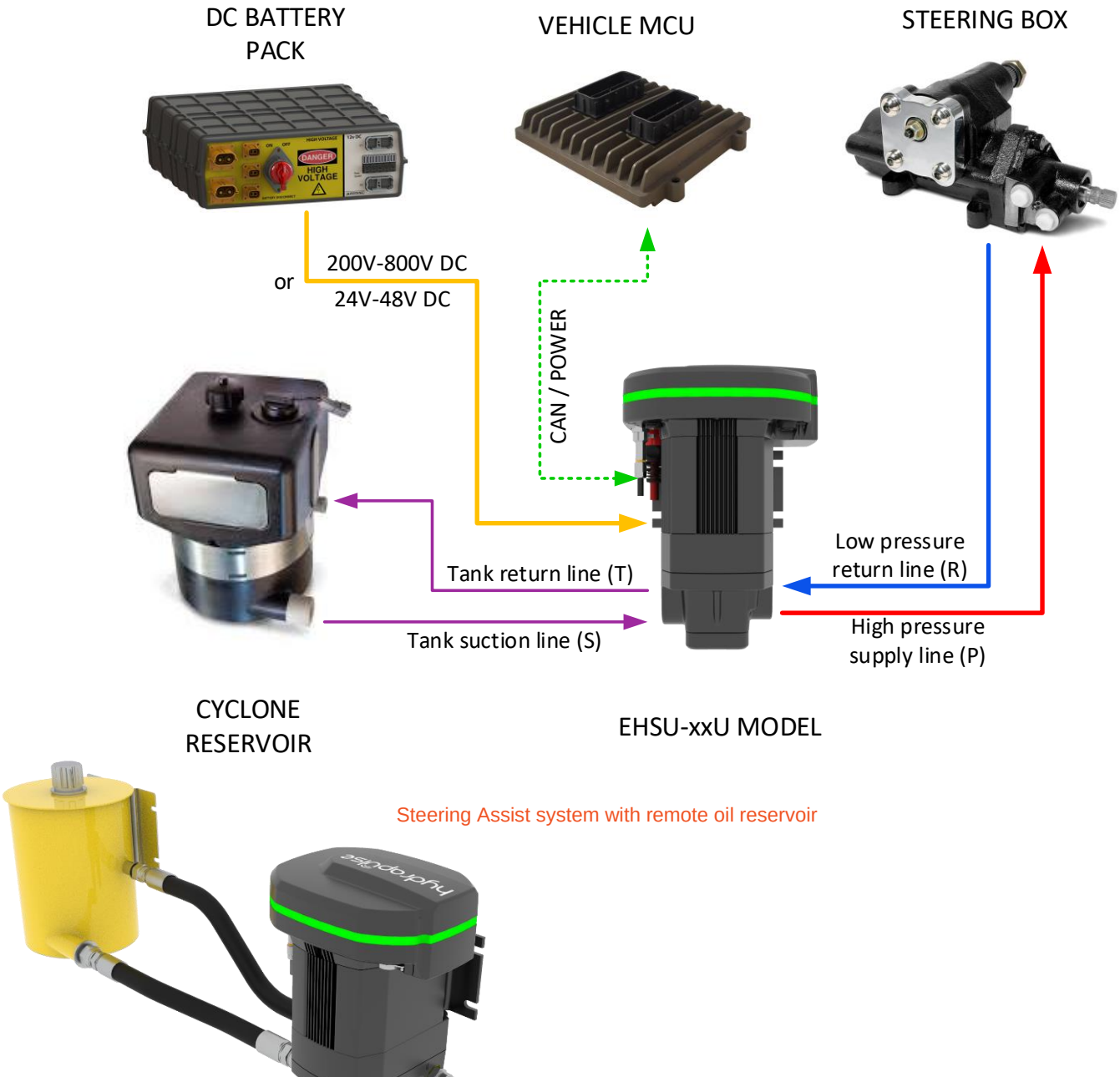


EHSU-2.5UPR MODEL

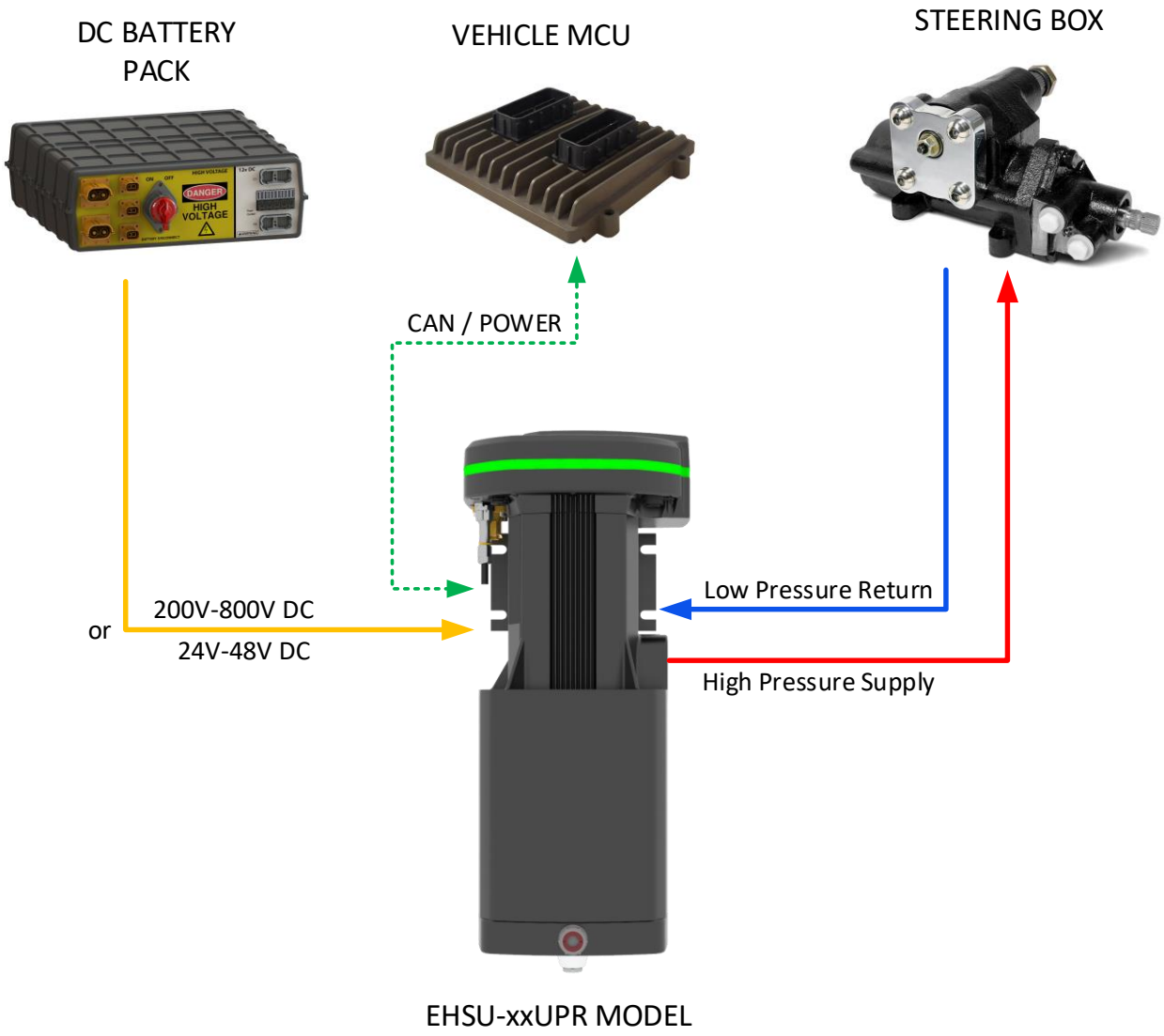
2.2 Types of Steering Systems

2.2.1 Steering Assist System

There are two types of systems that are typically utilized for vehicle steering assist. A steering assist system is where there is a direct, mechanical linkage to the steering mechanism and the EHSU only provides “power steering”. The high-pressure hydraulic supply assists the mechanical actuation of the steering linkages. You can either implement a remote hydraulic reservoir or utilize the EHSU with integrated reservoir (option “R”). In steering assist applications, the EHSU would be set to operate in only ONE direction. This would also utilize the uni-directional pump option code “U” in ordering.



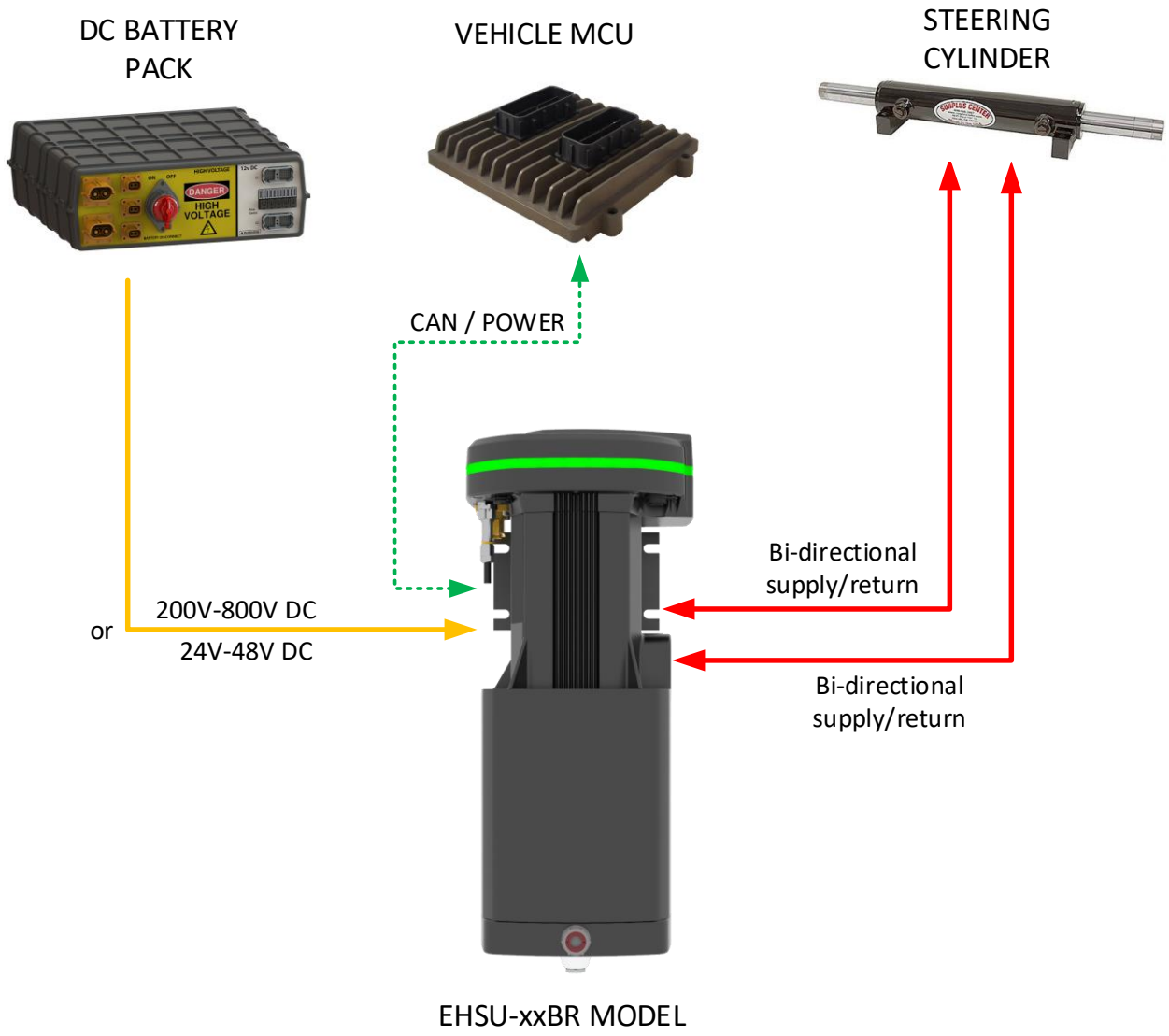
Steering Assist system with remote oil reservoir



Steering Assist system with integrated oil reservoir

2.2.1 E-Steering System (Steer-by-Wire)

An E-steering system does not have a mechanical connection to the steering linkage and is typically used for tag axles or other non-front axles applications. This type of steering system uses a hydraulic cylinder (actuator) to move the linkage components. In E-Steering applications, the EHSU would be set to operate in TWO directions. This would also utilize the bi-directional pump option code "B" in ordering. In this system, the EHSU would reverse direction of the motor/pump to control the actuator direction.



E-Steering (Steer-by-wire) system with integrated oil reservoir

2.3 Modes of Operation

There are two main types of operational modes for the EHSU units. One is true power on demand mode (TPDM) and one is standby power on demand (SPDM).

2.3.1 TPDM Mode

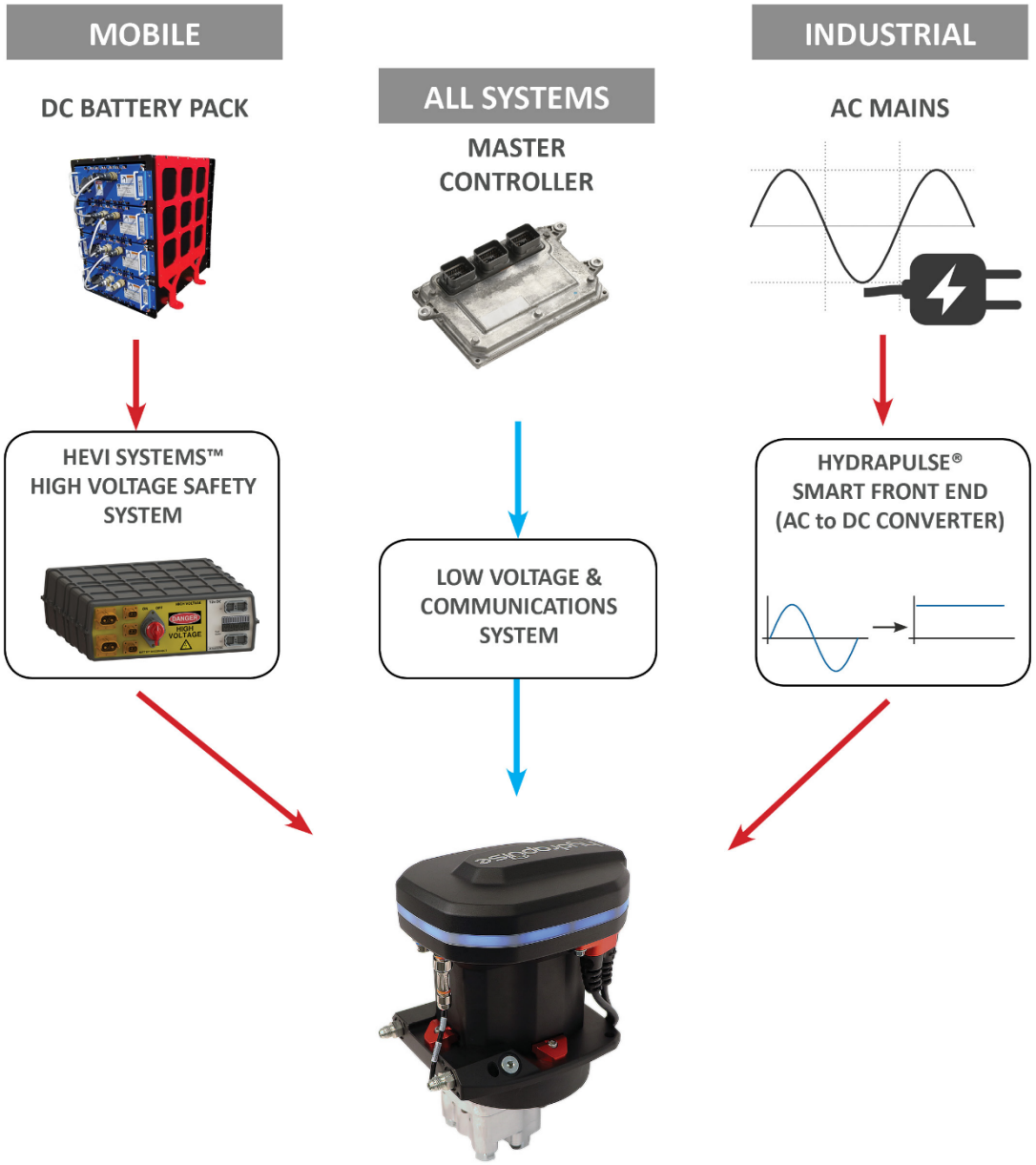
Typically, the Hydrapulse® EHSU can react from zero pressure to system pressure in under 60ms so some applications can utilize TPDM mode where the EHSU is completely OFF and providing no flow or pressure except when a steering command is called for. This type of mode would normally be used in E-Steering systems and off-highway vehicle platforms.

2.3.2 SPDM Mode

In Standby Power On Demand Mode, the Hydrapulse® EHSU will maintain an "idle" state where it maintains a given idle flowrate setpoint. Then, when more flow is called for, the EHSU will spool up instantly to full system flowrate to maintain steering system pressure. This is called "Pressure Pump Mode" as outlined in Chapter 3.

3 Electrical Wiring

The Hydrapulse® unit was developed to operate in both mobile vehicle applications and industrial facility applications. In mobile applications, the primary power comes from a DC battery pack and in industrial applications the power comes from the AC mains into a facility. When installing the Hydrapulse®, specific safety, circuit protection, and disconnect means must be implements. For mobile applications, please refer to Chapter 3.2.1 and for industrial applications, please refer to Chapter 3.3.1. Low voltage and communications information is below.



3.1 Low Voltage and Communications

The electrical architecture for all Hydrapulse® units is the same regardless of voltage, power, or frame sizes. Low voltage (9-36vdc) power to operate all electrical circuitry is provided to the orange M12 connector and high voltage (24/48vdc or 200-800vdc) to drive the PM motor is provided to the high-power connector.

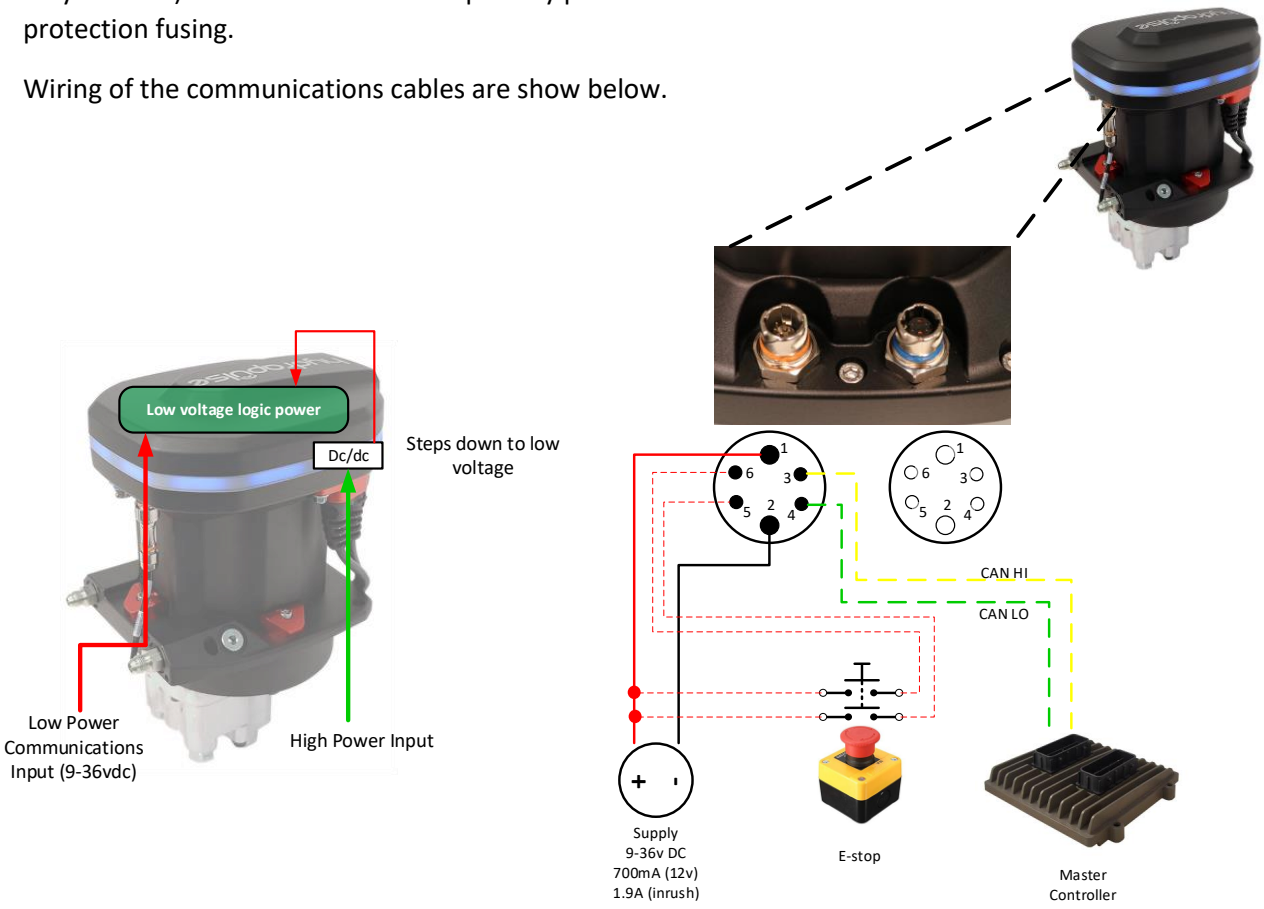
For programming, configuration, debugging, etc. of the Hydrapulse, you only need to provide low voltage power through the orange M12 connector.

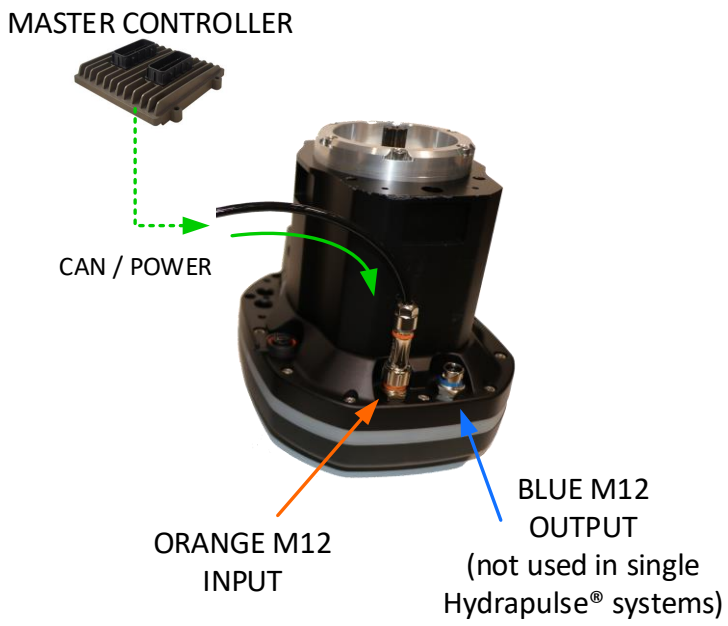
The primary purpose of the step-down dc/dc converter it to allow the Hydrapulse to act as a master unit with no controller or if the control unit can only supply CAN J1939 communications.
We recommend supplying low power through the communications cable. This allows for programming, troubleshooting, etc. without high power hooked up. In many instances, in high voltage mobile vehicles, you do not want the high voltage battery bus powered when you are programming, updating firmware, etc.

3.1.1 Low Voltage Communications Circuit

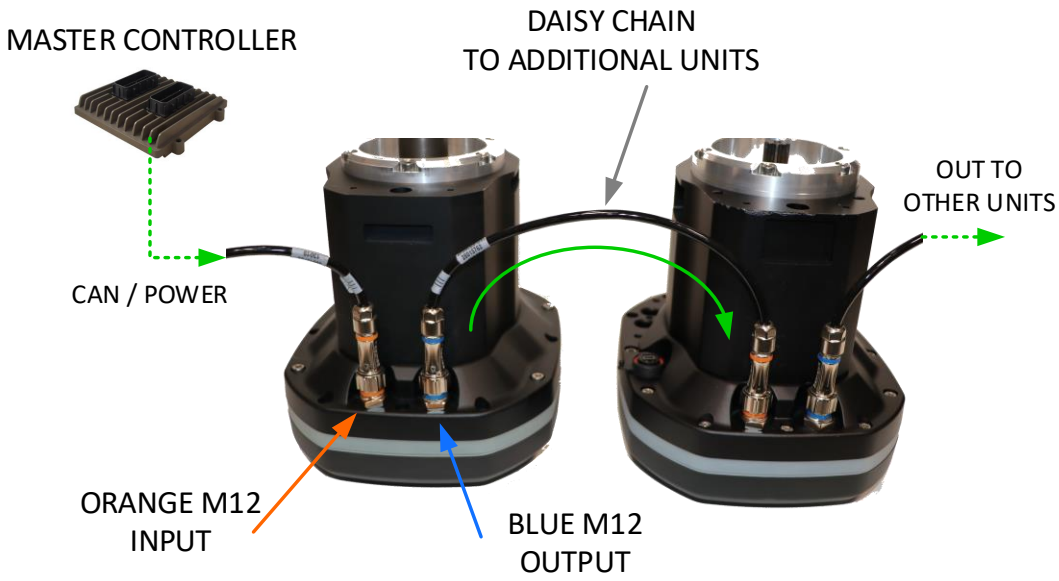
Each Hydrapulse® unit utilizes one M12 6-pin cable for its low power input and CAN communications. This is the ORANGE connector on the EHPU model (the EHPU has two M12 connectors while the EHSU only has one). All units have reverse polarity protection and internal self-protection fusing.

Wiring of the communications cables are show below.





Single Hydrapulse® system communications wiring



Multiple Hydrapulse® system communications wiring

3.1.2 Low voltage communications cables

EHPU models have one cable to supply 9-36vdc power and CAN J1939 communications into the unit and one cable to supply 9-36vdc power and CAN J1939 communications out of the unit. Each communications cable is supplied with a 6-pin metal sealed M12 Samtec Acclimate Bayonet style connector. These two connectors are keyed differently to prevent incorrect installation.

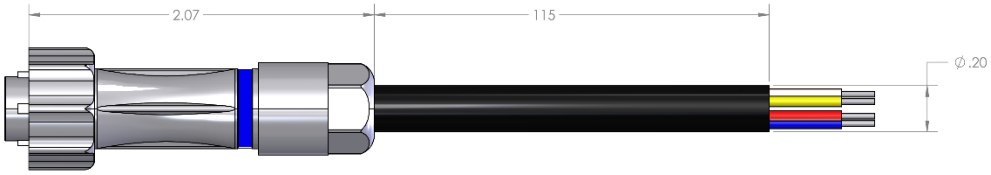
Orange M12 (Power/Comms IN)

Blue M12 (Power/Comms OUT)

Name	Pin	Color	Description
VCC	1	Brown	9-36V control power (in)
GND	2	Red	9-36V control ground (in)
CAN-H	3	Orange	CAN High in
CAN-L	4	Yellow	CAN Low in
STO-0	5	Green	E-Stop 0 – in (STO)
STO-1	6	Blue	E-Stop 1 – in (STO)

Name	Pin	Color	Description
VCC	1	Brown	9-36V control power out
GND	2	Red	9-36V control ground out
CAN-H	3	Orange	CAN High – out
CAN-L	4	Yellow	CAN Low - out
STO-0	5	Green	E-Stop 0 - out
STO-1	6	Blue	E-Stop 1 - out

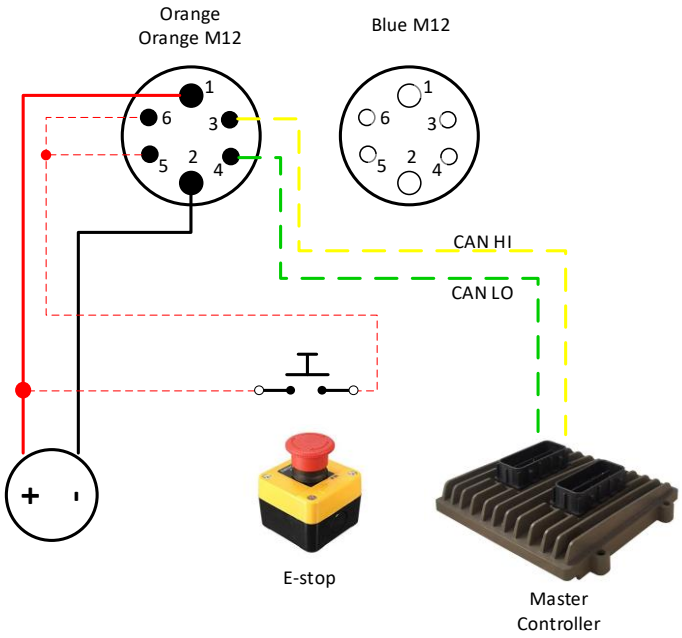
Standard cable lengths are 115 inches (3 meters)



Weather caps are available for both the cable and connector sides.

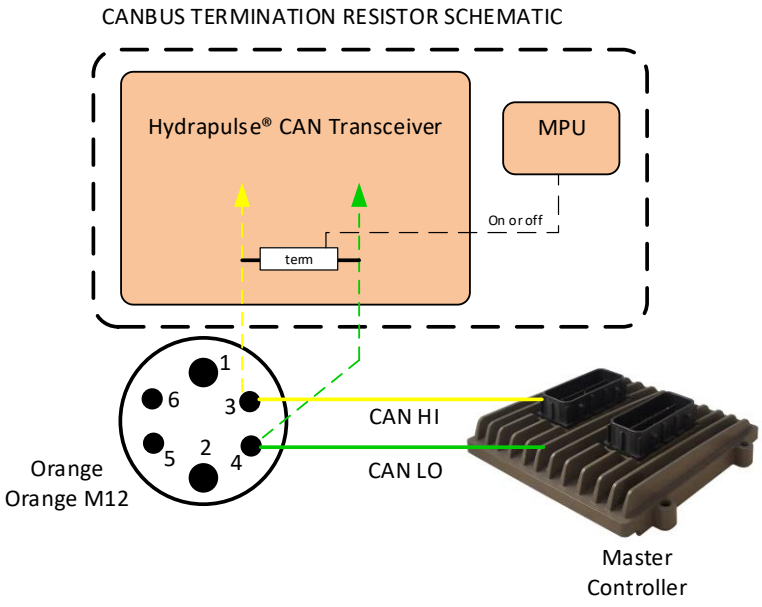
3.1.3 Emergency Stop Circuit (E-stop)

All Hydrapulse units are configured to accept an E-stop switch circuit. How these circuits are wired vary by country, state, and regional codes and regulations. It is the responsibility of the owner or installer to follow all applicable codes that may apply to their specific application.



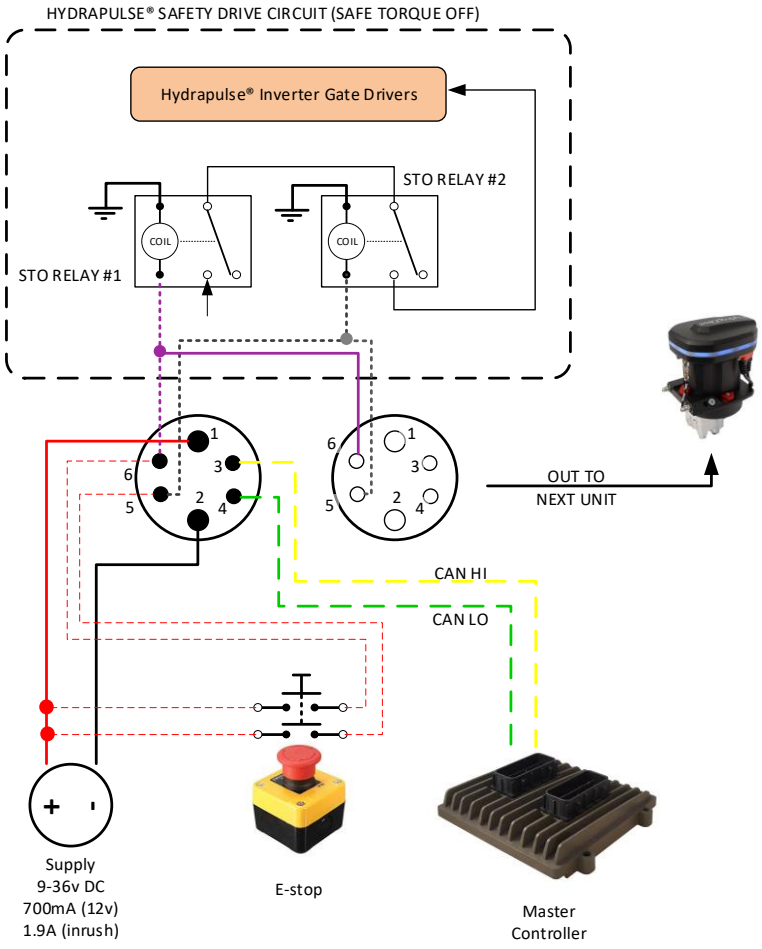
3.1.1 Termination Resistor

Every Hydrapulse® is equipped with a software selectable termination resistor. This resistor can be turned off or on via a software bit.



3.1.1 Safe Torque Off (STO)

The Hydrapulse is designed to be implemented into systems that require a STO function. This is typically industrial applications that must adhere to specific machine safety protocols and correct implementation of this type of system must be done by experts. There are two functional safety relays inside each Hydrapulse that provide redundant shut down of any possible torque output from the motor. A typical STO schematic is shown below.



Typical STO Circuit functionality

3.2 High Power Input

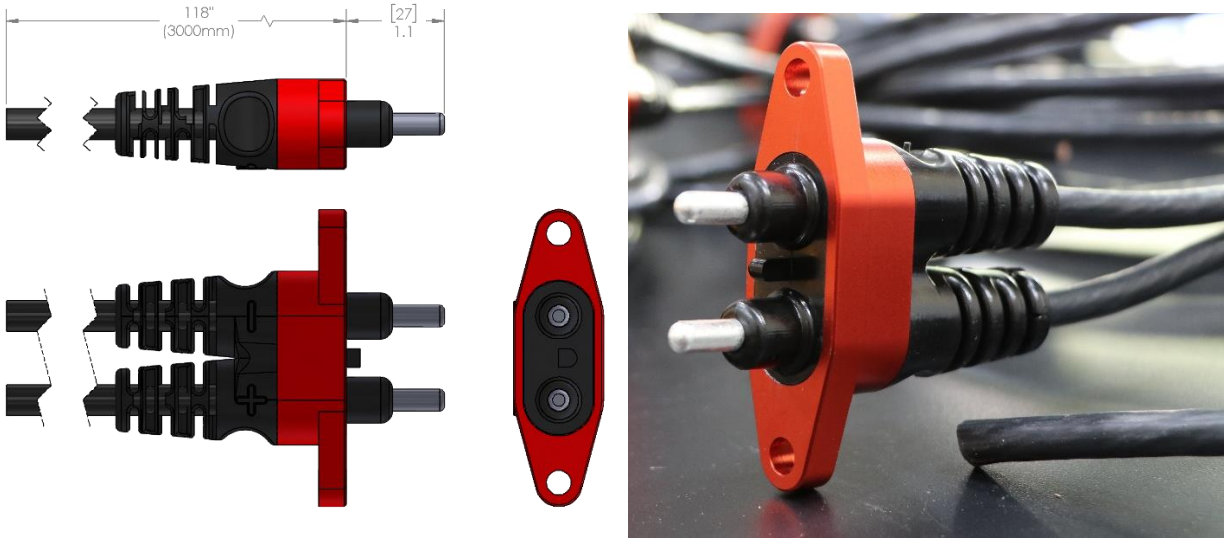
There are two styles of power connectors for the Hydrapulse® EHSU. One is for low voltage (24v to 48v) and one is for high voltage (200v to 800v).

The high voltage connectors are Amphenol Magnamate™ ATHP series with integrated high voltage interlock loop pins (HVIL).

Magnamate Cable (high current)

Mini-Magnamate Cable (low current)

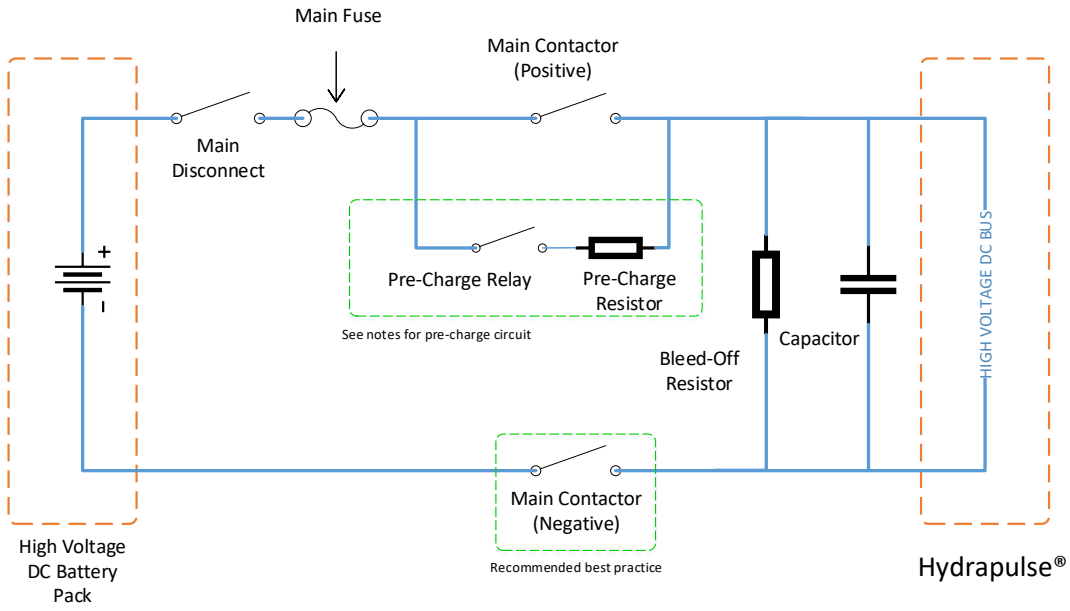
The low voltage cable is a made with Amphenol radsok contact technology and is rated for up to 200 amps DC.



Hydrapulse low voltage cable

3.2.1 Mobile High Voltage safety system

When the Hydrapulse® is the only component in the high voltage circuit, a pre-charge circuit is not required but it is recommended.



Typical high voltage circuit

3.2.2 Main Fusing

Fuse protection for each Hydrapulse® is recommended to be a Class J High Speed type. Refer to the table below for fuse size.

Model Power Level	Rated Current	Fuse Size
1.5KW EHSU/EHPU	33 A	40 A
2.5KW EHSU/EHPU	3.3 A / 7 A	10 A
10kW EHSU/EHPU	17 A	25 A
30kW EHPU	75 A	100 A

3.2.3 Capacitance

Refer to the table below for Hydrapulse onboard capacitance for sizing your pre-charge system.

Model Power Level	Onboard Capacitance (uF)
1.5KW EHSU/EHPU	600
2.5KW EHSU/EHPU	500
10kW EHSU/EHPU	750
30kW EHPU	1200

4 Controls

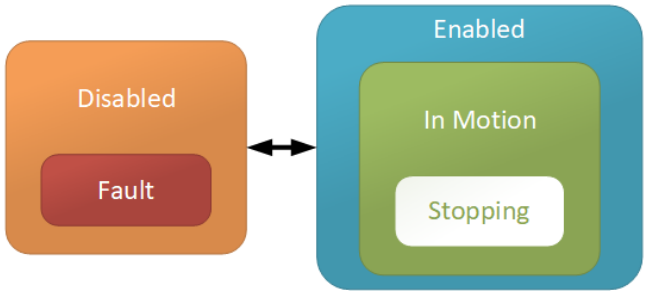
4.1 Operation

The following sections describe the methods to operate both the EHPU and the EHSU models of the Hydrapulse®.

4.1.1 Device States

Figure 4.1 below shows the different states of the Hydrapulse.

Figure 4.1: Hydrapulse state machine



The Hydrapulse powers up in the *Disabled* state. All configuration must be done in this state. To operate the device it must be moved to the *Enabled* state. In this state, only Operational Control parameters are valid (refer below to Section 4.1.2). Table 4.1 lists the device states and summarizes the transitions between the states.

Table 4.1: Hydrapulse state description

State	State Transitions	Feedback	Valid Communication	Notes
Disabled	to/from *Enabled* by setting DEVICE ENABLE	ENABLE STATE	All communication valid	
Fault	to *Disabled* by resolving fault from *Enabled* when fault is detected	ANY FAULT	All communication valid	Must resolve fault before moving device to *Enabled* state. Refer to Section 4.3
Enabled	to/from *Disabled* by setting DEVICE ENABLE	ENABLE STATE	Only Operational Control Commands	
In Motion	to *Stopping* by setting START/STOP to stop from *Enabled* by setting START/STOP to start and setting a non-zero COMMAND SETPOINT	IN MOTION	Only Operational Control Commands	
Stopping	to *Enabled* by waiting for device to stop from *In Motion* by setting START/STOP to stop	STOPPING	Only Operational Control Commands	

4.1.2 Operational Control Parameters

Operational Control Parameters allow the device to transition between states and control the output of the Hydrapulse when in operation. All Operational Control Parameters are listed below in Table 4.2. Refer to Section 5.2.2 for J1939 details.

Table 4.2: Operational Control Parameters

Parameter	Type	Notes
DEVICE ENABLE	Boolean	Disables/Enables device
START/STOP	Boolean	Commands motion/stops motion
COMMAND SETPOINT	Signed Value	Updates output reference. Either flowrate or pressure base on PUMP MODE

4.1.3 Constant Flow Mode

When PUMP MODE is configured for constant flow, the COMMAND SETPOINT parameter sets the speed of the motor on the drive side of the Hydrapulse. The output of the motor will continuously adjust to maintain the set speed.

Acceleration & Deceleration Slew Rates

The Configuration Parameters, ACCELERATION and DECELERATION will set the slew rate for the commanded speed of the motor. They apply every time the COMMAND SETPOINT is updated.

Pressure Limiting

The motor will adjust the output to maintain speed, unless the pressure reading reaches the MAX PRESSURE setpoint. In this case, the motor will scale back its output to maintain that pressure so as not to exceed the setting.

The PRESSURE/FLOW LIMITING warning indicates if the device is pressure limited.

4.1.4 Constant Pressure Mode

When PUMP MODE is configured for constant pressure, the COMMAND SETPOINT parameter sets the target pressure of the pump side of the Hydrapulse. The output of the motor will continuously adjust to maintain the set pressure.

Flow Limiting

The motor will adjust the output to maintain pressure, unless the speed reaches the MAX SPEED setpoint. In this case, the motor will scale back its output to maintain that speed so as not to exceed the setting.

4.1.5 Process Data (Feedback to User)

All device states, operational settings, and measured values are fed back to the user as Process Data. CAN SCHEDULING configures if Process Data is broadcasted automatically and the frequency at which it is broadcasted at. Table 4.3 below lists all data that is fed back to the user. The specific data format and J1939 PGN information is found in Section 5.2.4.

Table 4.3: Process Data list and description

Name	Type	Description	Notes
Device Operational State			
ENABLE STATE	Boolean	Device disabled/enabled	
IN MOTION	Boolean	Device in motion/stopped	
STOPPING	Boolean	Device decelerating/not decelerating	
Operational Settings			
PUMP MODE	Boolean	Constant Flow/Constant Pressure	Reads configuration set by user
COMMAND SETPOINT	Signed Value	Target setpoint in flowrate or pressure	Reads operational parameter set by user
Measured Value			
FLOWRATE	Signed Value	Measured flowrate (speed) of device motor	
PRESSURE A	Unsigned Value	Measured pressure of pressure port A	
PRESSURE B	Unsigned Value	Measured pressure of pressure port B	
DC BUS VOLTAGE	Unsigned Value	Measured Bus voltage	
DEVICE TEMPERATURE	Unsigned Value	Measured internal temperature of device hardware	
FLUID TEMPERATURE	Unsigned Value	Measured temperature of hydraulic fluid	

4.2 Configuration

Table 4.4 below lists all configuration parameters available to the user. Configuration is valid only while the device is disabled.

Table 4.4: Configuration parameters

Name	Type	Description	Notes
PUMP MODE	2 bit	Selects constant pressure or constant flow	Refer to Sections 4.1.3 and 4.1.4
INVERT DIRECTION	Boolean	Sets direction of rotation for motor. Reference is looking down on pump side	
INVERT PRESSURE SENSE	Boolean	Sets the high pressure port	
UNIDIRECTIONAL MODE	Boolean	Disables/enables bi-directionality	
HEARTBEAT DISABLE	Boolean	Disables/enables heartbeat functionality	Refer to Section 4.4.1
CAN SCHEDULING	Lookup table	Sets frequency of Process Data messages	Refer to Table 5.5
TUNING PARAMETERS	Lookup table	Selects the tuning for constant flow and constant pressure response	Select appropriate output response. Refer to Table 5.6
MAX SPEED	Unsigned Value	Sets the maximum output speed of the motor	Two parameters are available for both directions
ACCELERATION	Unsigned Value	Sets the acceleration slew rate for constant flow	Two parameters are available for both directions
DECELERATION	Unsigned Value	Sets the deceleration slew rate for constant flow	Two parameters are available for both directions
MAX PRESSURE	Unsigned Value	Sets the maximum pressure output for constant flow mode	Two parameters are available for both directions
MAX FAULT PRESSURE	Unsigned Value	Sets the pressure threshold where the device would fault	Expressed as a percentage above MAX PRESSURE

4.2.1 Read Device Configuration

The current device configuration can be read by requesting particular J1939 PGNs. The specific PGNs are listed in Section 5.2.7.

Additionally, the device ID can be read to indicate product, firmware version, and serial number of the drive side. Refer to Section 5.2.7.

4.2.2 Burn to EEPROM and Factory Reset

To save the current device configuration on power cycle, the configuration parameters can be burned into EEPROM. This action burns all parameter settings into EEPROM.

Additionally, all parameters can be reset to factory default settings. This also performs a burn function which will overwrite any previously burned settings.

Refer to Section 0 for specifics.

4.3 Faults and Warnings

The Hydrapulse uses a multitude of sensors to monitor the operation and environment of the device. To ensure safe operation, there are multiple faults and warnings that can occur. A fault will disable the device, while a warning will continue operation with reduced power output or performance. The following describe the different faults and warnings that can occur.

4.3.1 Faults

Table 4.5 below describes all the faults that may occur on the device.

Table 4.5: Hydrapulse fault list with description

Fault	Description	Clear Fault
OVER CURRENT FAULT	Main DC Bus fuse blown	Consult factory
OVER VOLTAGE FAULT	DC Bus voltage exceeds 55V	CLEAR FAULT command
UNDER VOLTAGE FAULT	DC Bus voltage under 20V	Clears when Bus voltage reaches 20V
OVER TEMPERATURE FAULT	Device temperature exceeds 125°C	CLEAR FAULT command
FLUID OVER TEMP FAULT	Fluid temperature exceeds 80°C	CLEAR FAULT command
SAFE TORQUE OFF	E-Stop open	CLEAR FAULT command
HEARTBEAT IN NOT DETECTED	No communication from host controller within 1 second (when heartbeat is enabled)	CLEAR FAULT command
OVER PRESSURE FAULT	Pressure exceeds 4000 psi or pressure set with MAX PRESSURE and MAX FAULT PRESSURE (whichever is lower)	CLEAR FAULT Command
INVERTER FAULT	Motor drive hardware failure	Consult factory
DEVICE HARDWARE FAULT	Internal hardware failure	Consult factory
ANY FAULT	Any of the above faults has occurred	

Clear Fault Command

Many faults require the host controller to issue the CLEAR FAULT command. Refer to Section 5.2.3.

NOTICE

It is the responsibility of the user to ensure the cause of the fault is resolved before clearing. Failure to do so may lead to device or system failures.

4.3.2 Warnings

Table 4.6 below describes the warnings and associated behavior on the device.

Table 4.6: Hydrapulse warning list with descriptions

Warning	Description	Notes
PRESSURE/FLOW LIMITING	Constant Pressure: maximum speed is reached Constant Flow: maximum pressure is reached	MAX SPEED and MAX PRESSURE set the output thresholds. Refer to Sections "Pressure Limiting" and "Flow Limiting"
TORQUE OUTPUT LIMITING	Device maximum output is reached	Refer to Section "Torque Output Limiting"

Torque Output Limiting

The maximum output of the motor is internally fixed based on the cooling requirement of the device. If the pump side is loaded such that the maximum output is reached, the device will remain operating at this max output. The TORQUE OUTPUT LIMITING warning indicates if the device maximum output is reached.

4.4 Other Modes

4.4.1 Heartbeat

When heartbeat is enabled (default), an Operational Control PGN must be sent at a frequency of 1 Hz (once per second) or greater when the device is enabled. If an Operational Control PGN is not received within 1 second, the device will stop motion and enter an error state.

Heartbeat can be disabled through the HEARTBEAT DISABLE parameter.

4.5 L.E.D. Status Indication

The Hydrapulse Smart Pump has an LED light ring status indicator visible during operation. This is used to visually indicate status of the Hydrapulse. For further status details such as fault codes, the user interface can give all information needed for troubleshooting and correcting issues. Table 4.7 below lists the following LED pattern and description.

Table 4.7: LED description

LED Color & Pattern	Description
Flash Orange	Device is booting up
Orange	Device is in disabled state
Blue	Device is in enabled state and stopped
Green	Device is in enabled state and running
Flash Red	Fault has occurred
EEPROM	
White	EEPROM burn complete
Firmware Update	
Flash Blue	USB detected
Fast Flash Blue	Firmware update in progress
White	Firmware update complete
Fast Flash Red/Orange	Corrupt firmware

5 J1939 Communication

The Hydrapulse device follows the J1939 communication standard. Reference SAE J1939 documents for more details regarding the communication standard.

5.1 Network Configuration

5.1.1 Network Requirements

Baud Rate	250 kb/s (125 kb/s, 500 kb/s, 1000 kb/s contact Hydrapulse if required)
Termination Resistor	Yes (contact Hydrapulse if no resistor required)

5.1.2 Device Address

Upon device start-up, each device will perform an auto-assign routine to claim an available address. The device will attempt to claim address 100 (0x64). If already taken, the device will increment the address by 1 and reattempt.

5.2 PGN Mapping

The following sections detail the specific PGNs and their data fields transmitted and received by the Hydrapulse device.

5.2.1 Configuration PGNs

There are eight configuration PGNs associated with the device: four transmit (TX) and four receive (RX). The data fields in the four transmit PGNs match those in the receive PGNs. The receive PGNs are used to configure the device while the transmit PGNs are used to report back current device configuration.

Each time the device receives a configuration PGN it will respond with the associated transmitted configuration PGN. This allows the user to confirm whether configuration was successful. The device may not accept or may modify received configuration parameters if they are invalid or out of range. For example, if a MAX SPEED+ parameter greater than 4,000 rpm, the device will cap it at 4,000. The transmit configuration PGNs can additionally be requested at any time following the J1939 protocol. Refer to Section 5.3.1 for more information.

Table 5.1 summarizes the configuration PGNs available on the device.

Table 5.1: Summary of Configuration PGNs

	RX PGN	TX PGN	Data
Configuration #1	0x006600	0x00F2C0	Table 5.2
Configuration #2	0x006700	0x00F2D0	Table 5.3
Configuration #3	0x006800	0x00F2E0	Table 5.4
Configuration #4	0x006900	0x00F2F0	Reserved for future use

Table 5.2: Configuration Command #1

PGN 0x006600 (RX) / 0x00F2C0 (TX)						
Description	**Length**	**Bit Offset**	**Units**	**Scale**	**Offset**	**Notes**
PUMP MODE	2	0	00: Constant Flow (default) 01: Constant Pressure 10 & 11: Reserved			
INVERT DIRECTION	1	2	0: CCW is positive direction (default) 1: CW is positive direction			Rotation when looking down at pump
INVERT PRESSURE SENSE	1	3	0: Port A is HIGH-SIDE PRESSURE (default) 1: Port B is HIGH-SIDE PRESSURE			
UNIDIRECTIONAL MODE	1	4	0: Bidirectional mode (default) 1: Unidirectional mode			When set, unidirectional mode only allows motion in the + direction
Reserved	1	5	N/A			
HEARTBEAT DISABLE	1	6	0: Heartbeat mode is enabled (default) 1: Heartbeat mode is disabled			Refer to Section 4.4.1
Reserved	17	7	N/A			
CAN SCHEDULING	4	24	Refer to Table 5.5			All *Process Data* PGNs and *Fault/Warning* PGN are sent at this frequency
Reserved	4	28	N/A			
TUNING PARAMETERS	4	32	Refer to Table 5.6			
Reserved	28	36	N/A			

Table 5.3: Configuration Command #2

PGN 0x006700 (RX) / 0x00F2D0 (TX)						
Description	**Length**	**Bit Offset**	**Units**	**Scale**	**Offset**	**Notes**
ACCELERATION+	8	0	rpm/msec	1 rpm-msec/bit	0	Acceleration slew rate for + speeds. Refer to Table 5.7
ACCELERATION-	8	8	rpm/msec	1 rpm-msec/bit	0	Acceleration slew rate for – speeds. Refer to Table 5.7
DECELERATION+	8	16	rpm/msec	1 rpm-msec/bit	0	Deceleration slew rate for + speeds. Refer to Table 5.7
DECELERATION-	8	24	rpm/msec	1 rpm-msec/bit	0	Deceleration slew rate for – speeds. Refer to Table 5.7
MAX FAULT PRESSURE	8	32	%	1 %/bit	100%	Sets pressure fault point. Based on MAX PRESSURE+ and MAX PRESSURE-. Refer to Table 5.7
Reserved	24	40	N/A			

Table 5.4: Configuration Command #3

PGN 0x006800 (RX) / 0x00F2E0 (TX)						
Description	**Length**	**Bit Offset**	**Units**	**Scale**	**Offset**	**Notes**
MAX SPEED+	16	0	rpm	1 rpm/bit	0	Max speed in + direction. Unsigned 16 bit, little endian Example: 0x07D0 sets max speed of 2000 rpm. Refer to Table 5.7
MAX SPEED-	16	16	rpm	1 rpm/bit	0	Max speed in - direction. Unsigned 16 bit, little endian. Refer to Table 5.7
MAX PRESSURE+	16	32	psi	1 psi/bit	0	Max pressure in + direction. Unsigned 16 bit, little endian Example: 0x03E8 sets max pressure of 1000 PSI. Refer to Table 5.7
MAX PRESSURE-	16	48	psi	1 psi/bit	0	Max pressure in - direction. Unsigned 16 bit, little endian. Refer to Table 5.7

Table 5.5: CAN Scheduling Options

Data Bits (Hex)	Description
0x0, 0xF	Invalid Setting
0x1	All scheduled PGNs transmitted at 100 msec intervals
0x2	Transmitted at 200 msec intervals
0x3	Transmitted at 300 msec intervals
0x4	Transmitted at 400 msec intervals
0x5	Transmitted at 500 msec intervals (default)
0x6	Transmitted at 600 msec intervals
0x7	Transmitted at 700 msec intervals
0x8	Transmitted at 800 msec intervals
0x9	Transmitted at 900 msec intervals
0xA	Transmitted at 1 sec intervals
0xB	Transmitted at 1100 msec intervals
0xC	Transmitted at 1200 msec intervals
0xD	Transmitted at 1300msec intervals
0xE	PGNs only available on request

Table 5.6: Tuning Parameter Options

Data Bits (hex)	Description
0x0, 0xF	Invalid Setting
0x1	Default Tuning (default)
0x2 – 0xE	Reserved

Table 5.7: Valid Range and Default Values for Parameters

Parameter	Min	Max	Default	Example
ACCELERATION+	TBD	TBD	20	
ACCELERATION-	TBD	TBD	20	
DECELERATION+	TBD	TBD	20	
DECELERATION-	TBD	TBD	20	
MAX FAULT PRESSURE	TBD	TBD	50	
MAX SPEED+	TBD	4000	4000	
MAX SPEED-	TBD	4000	4000	
MAX PRESSURE+	TBD	4000	3000	
MAX PRESSURE-	TBD	4000	3000	

5.2.2 Operational Control PGNs

There are two receive (RX) Operational Control PGNs associated with the device.

Table 5.8 summarizes the Operational Control PGNs available on the device

Table 5.8: Summary of Operational Control PGNs

	RX PGN	Data
Operational Control #1	0x006400	Table 5.9
Operational Control #2	0x006500	Reserved for future use

Table 5.9: Operational Control Command

PGN 0x006400 (RX)						
Description	**Length**	**Bit Offset**	**Units**	**Scale**	**Offset**	**Notes**
DEVICE ENABLE	1	0	0: Disable device 1: Enable device			
START/STOP	1	1	0: Command Stop 1: Command Motion			
Reserved	6	2	N/A			
COMMAND SETPOINT	16	8	rpm or psi	1 rpm/bit or 1 psi/bit	0	Signed 16 bit, little endian Pump Mode determines units. Constant Flow sets rpm/Constant Pressure sets psi
Reserved	40	24	N/A			

5.2.3 Auxiliary Command PGN

There is one receive (RX) Auxiliary Command PGN associated with the device. The data field is broken into Groups, where a particular group value will perform a specific operation, such as Clear Faults.

Table 5.10: Auxiliary Command

PGN 0x006A00			
Description	**Length**	**Bit Offset**	**Notes**
Reserved	56	0	N/A
Group 1	4	56	0000: No Function 0001: Clear Faults
Group 2	4	60	0000: No Function 0001: Burn to EEPROM 0010: Reset Factory Default Parameters

5.2.4 Process Data PGNs

There are five transmit (TX) Process Data PGNs associated with the device. The Process Data is used to give live feedback regarding the state of operation and sensor values. They are automatically transmitted at the frequency set by the CAN SCHEDULING parameter in Table 5.2, or can be transmitted by request by the host controller.

Table 5.11 summarizes the Process Data PGNs available on the device.

Table 5.11: Summary of Process Data PGNs

	TX PGN	**Data**
Process Data #1	0x00F250	Table 5.12
Process Data #2	0x00F260	Table 5.13
Process Data #3	0x00F270	Table 5.14
Process Data #4	0x00F280	Table 5.15

Process Data #5[1]	0x00F290	Reserved for future use

Table 5.12: Process Data #1

PGN 0x00F250						
Description	**Length**	**Bit Offset**	**Units**	**Scale**	**Offset**	**Notes**
Time	8	0	msec	100 msec/bit	0	Time at which data was sampled. Allows proper syncing of all transmitted data.
PUMP MODE	2	8	00: Constant Flow 01: Constant Pressure 10 & 11: Reserved			
ENABLE STATE	1	10	0: Device Disabled 1: Device Enabled			
IN MOTION	1	11	0: Device not in motion 1: Device in motion			
STOPPING	1	12	0: Device not decelerating 1: Device decelerating			
Reserved	18	13	N/A			
COMMAND SETPOINT	16	32	rpm or psi	1 rpm/bit or 1 psi/bit	0	Signed 16 bit, little endian
Reserved	16	48	N/A			

Table 5.13: Process Data #2

PGN 0x00F260						
Description	**Length**	**Bit Offset**	**Units**	**Scale**	**Offset**	**Notes**
Time	8	0	msec	100 msec/bit	0	Time at which data was sampled. Allows proper syncing of all transmitted data.
Reserved	8	8	N/A			
FLOWRATE	16	16	rpm	1 rpm/bit	0	Signed 16 bit, little endian
HIGH-SIDE PRESSURE	16	32	psi	1 psi/bit	0	Unsigned 16 bit, little endian
LOW-SIDE PRESSURE	16	48	psi	1 psi/bit	0	Unsigned 16 bit, little endian

[1] As PGN 0x00F290 is marked reserved for future use, it is not broadcasted with the other Process Data PGNs at this time.

Table 5.14: Process Data #3

PGN 0x00F270						
Description	**Length**	**Bit Offset**	**Units**	**Scale**	**Offset**	**Notes**
Time	8	0	msec	100 msec/bit	0	Time at which data was sampled. Allows proper syncing of all transmitted data.
Reserved	8	8	N/A			
POSITION	16	16	revolutions	4 revs/bit	0	Signed 16 bit, little endian
Reserved	32	32	N/A			

Table 5.15: Process Data #4

PGN 0x00F280						
Description	**Length**	**Bit Offset**	**Units**	**Scale**	**Offset**	**Notes**
Time	8	0	msec	100 msec/bit	0	Time at which data was sampled. Allows proper syncing of all transmitted data.
DEVICE TEMPERATURE	8	8	°C	1 °C/bit	0	
FLUID TEMPERATURE	8	16	°C	1 °C/bit	0	
Reserved	24	24	N/A			
DC BUS VOLTAGE	16	48	Volts	1 V/bit	0	

5.2.5 System Data PGN

There is one transmit (TX) System Data PGN. It is transmitted upon request from the host controller.

Table 5.16: System Data

PGN 0x00F2B0						
Description	**Length**	**Bit Offset**	**Units**	**Scale**	**Offset**	**Notes**
Time Since Last Burn	16	0	msec	100 msec/bit	0	Time at which last 'Burn to EEPROM' command was completed. Refer to Table 5.10.
Reserved	48	16	N/A			

5.2.6 Faults and Warnings PGN

There is one transmit (TX) Faults and Warnings PGN associated with the device. It is automatically transmitted at the frequency set by the CAN SCHEDULING parameter in Table 5.2, or can be transmitted by request by the host controller.

Table 5.17: Device Faults and Warnings

PGN 0x00F240						
Description	**Length**	**Bit Offset**	**Units**	**Scale**	**Offset**	**Notes**
Time	8	0	msec	100 msec/bit	0	Time at which data was sampled. Allows proper syncing of all transmitted data.
OVER VOLTAGE FAULT	1	8	0: No Fault 1: Fault occurred			Clear error with 'Clear Error' command.
UNDER VOLTAGE FAULT	1	9	0: No Fault 1: Fault occurred			Automatically clears when bus voltage returns to proper range.
OVER TEMPERATURE FAULT	1	10	0: No Fault 1: Fault occurred			Clear error with 'Clear Error' command.
FLUID OVER TEMP FAULT	1	11	0: No Fault 1: Fault occurred			Clear error with 'Clear Error' command.
OVER PRESSURE FAULT	1	12	0: No Fault 1: Fault occurred			Clear error with 'Clear Error' command.
Reserved	3	13	N/A			
SAFE TORQUE OFF	1	16	0: No Fault 1: Fault occurred			Clear error with 'Clear Error' command.
HEARTBEAT IN NOT DETECTED	1	17	0: No Fault 1: Fault occurred			Clear error with 'Clear Error' command.
Reserved	6	18	N/A			
INVERTER FAULT	1	24	0: No Fault 1: Fault occurred			Consult Factory.
DEVICE HARDWARE FAULT	1	25	0: No Fault 1: Fault occurred			Consult Factory.
OVER CURRENT FAULT	1	26	0: No Fault 1: Fault occurred			Consult Factory.
Reserved	13	27	N/A			
PRESSURE/FLOW LIMITING	1	40				Continued operation with reduced output.
TORQUE OUTPUT LIMITING	1	41				Continued operation with reduced output.
Reserved	21	42	N/A			
ANY FAULT	1	63	0: No Fault 1: A Fault has occurred			Refer to above fault flags for specific fault

5.2.7 Device ID PGN

There is one transmit (TX) Device ID PGN. It is transmitted upon request from the host controller.

Table 5.18: Device ID

PGN 0x00F2A0			
Description	**Length**	**Bit Offset**	**Notes**
Device ID	8	0	0x00: HP-015-001
Firmware Version	24	8	Divided into 3 byte unsigned values. Example: 0x010001 is Version 1.0.1
Device Serial Number	16	32	Unsigned integer. Only represents last 4 digits of device serial number. Example: 0x01D8 is serial number 472.
Reserved	16	48	N/A

5.3 J1939 Quick Reference

The following sections are specific J1939 topics and specifications that are used by the Hydrapulse device. They are meant to be used as a quick reference. For a thorough treatment, refer to SAE J1939 documentation.

5.3.1 Request Specific PGNs

Some transmit (TX) PGNs on the Hydrapulse are available by request. This request is received through a reserved PGN. PGN 0x00EA00 is the request message PGN with 3 bytes of data, corresponding to the transmit PGN (TX) the host controller wishes to receive from the Hydrapulse.

PGN 0x00EA00 should be sent by the host controller with priority 6 and the three data bytes should be the requested PGN in little-endian.

6 Appendix A

6.1 Basic Troubleshooting

6.1.1 Firmware Update

Device firmware is field upgradable. For firmware files, visit hydrapulse.com.

Firmware Update Over USB

A standard flash drive is used to update firmware. The following steps are required to update firmware.

1. Load the desired .tza firmware file to the root directory of the flash drive.
2. With device powered down, install the flash drive to the USB port on the device.
3. Power up device and wait for the confirmation LED pattern:

Flashing Blue	USB detected
Fast Flashing Blue	Loading Firmware
White	Firmware update complete

Note: Do not rename the .tza file when loading onto the flash drive. Ensure that the file is in the root of the drive and that no other .tza files are also present.

Some versions of the Hydrapulse are equipped with a USB mini port.

If firmware is corrupted during the firmware update process (e.g. power loss during update), proceed with the instruction provided below. LED behavior may not work if firmware is corrupted.

Firmware Update Unsuccessful

If firmware update is unsuccessful, reload firmware using the same procedure in the previous section.

LED behavior may not operate correctly if firmware is corrupted. If LED behavior is not operating, it is recommended to power on the device with the flash drive installed and wait for 30 seconds before powering off. Then remove the flash drive and boot the device normally.

6.1.2 Data Export

Data export is not supported at this time. However, data logging may take place on the host controller.

6.2 Device Performance

Figure 6.1: HP-015-001 torque output

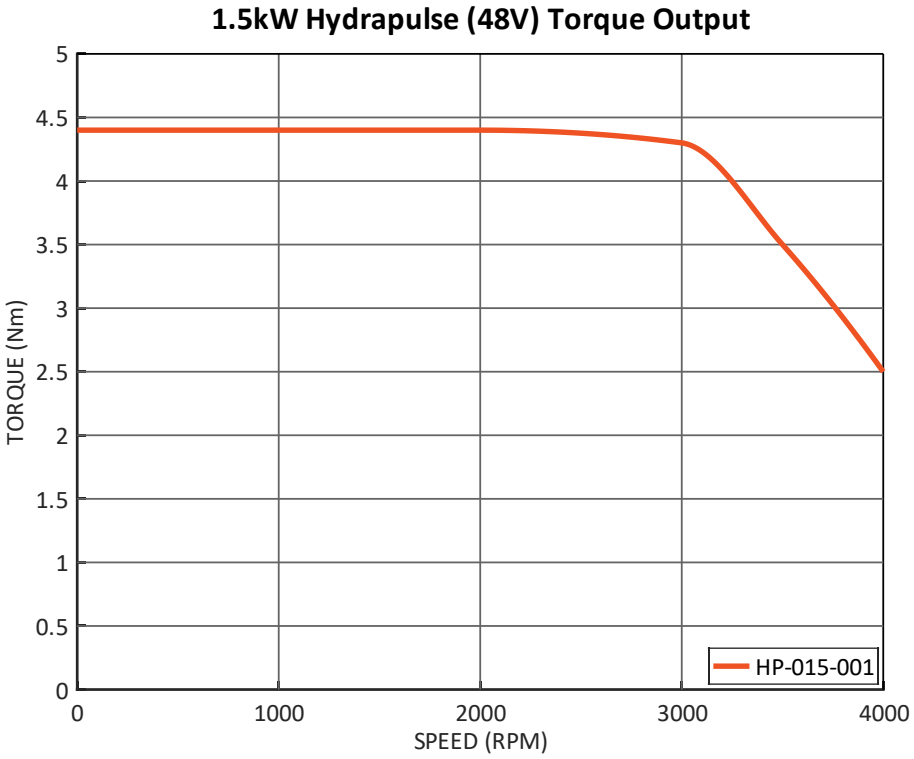


Figure 6.2: HP-015-001 with 2cc Base Pump pressure output

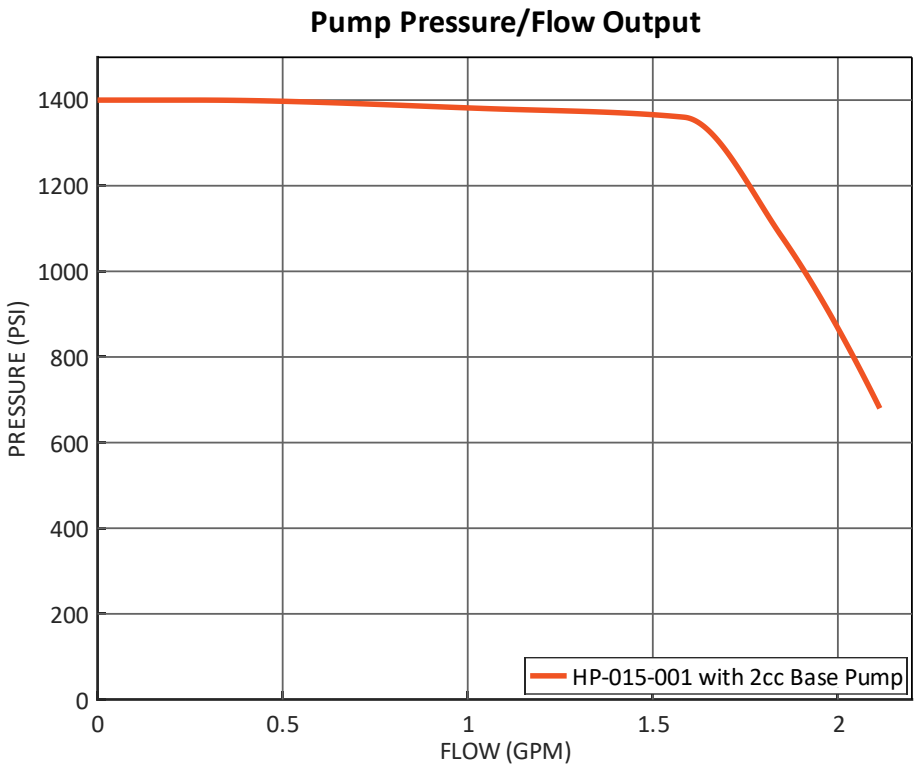


Figure 6.3: HP-015-001 power output (with Base Pump options)

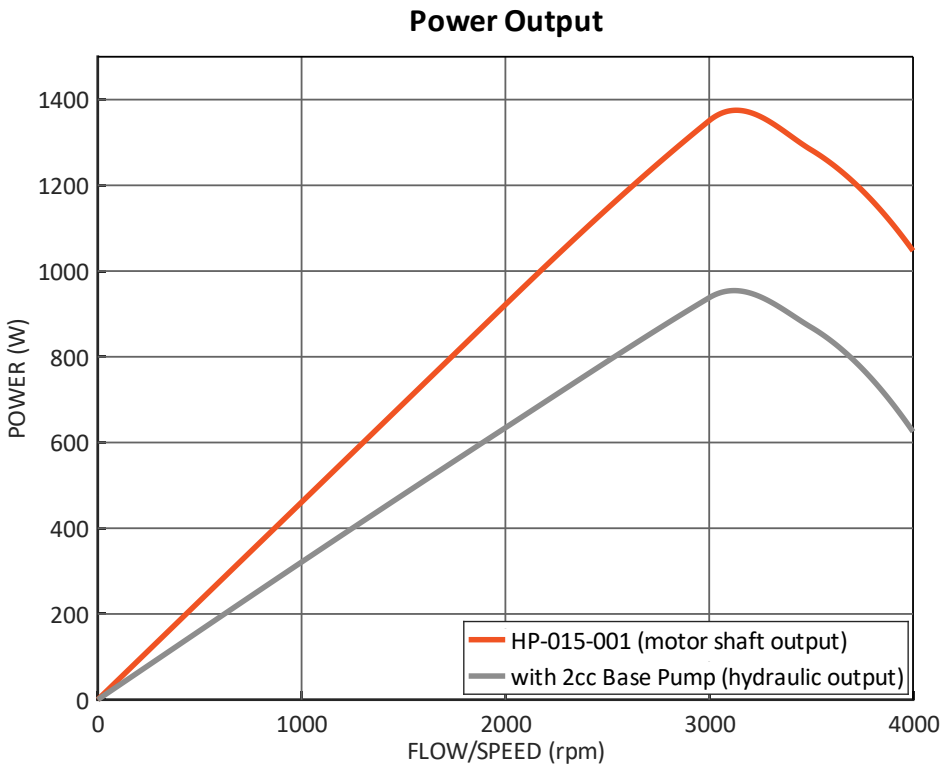


Figure 6.4: HP-015-001 efficiency (with Base Pump options)