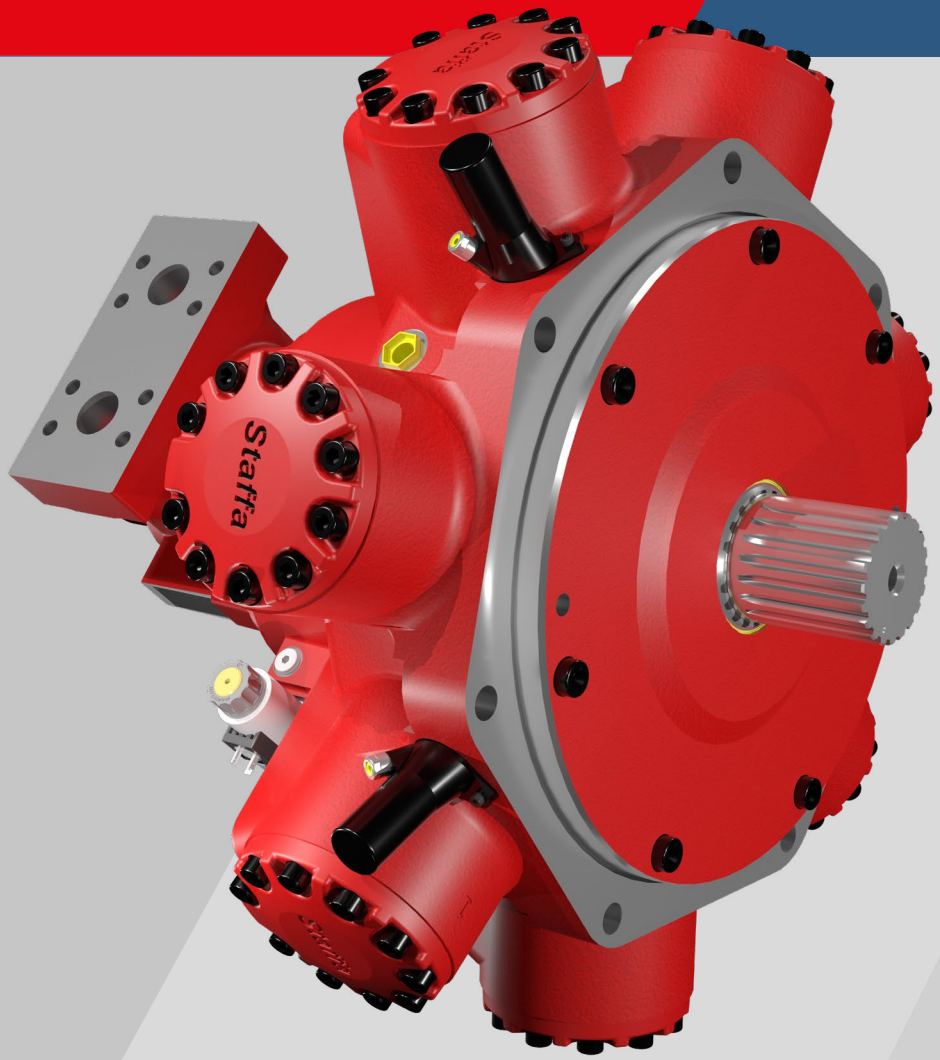
Kawasaki
Powering your potential

Precision Machinery Company

# Staffa
# Smart Motor

## Datasheet




PATENT PENDING

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# 1 Description / Features and Benefits

## Descriptions

The Staffa Smart/Smart+ Motor is a robust and reliable Staffa motor, with advanced digital displacement control engineered to power the next generation of high torque drives. Combining the compact power and robustness of the hydraulic drive with greater control and feedback, drive systems that use the Staffa Smart/Smart+ Motor will offer greater efficiency and, hence, lower environmental impact, especially at low speed; a useful stepping-stone towards automation; simple speed, positioning and synchronisation; advanced functionality based on precise and accurate control of displacement, such as constant torque, constant power or constant speed; and a more cost-effective drive solution throughout the equipment's lifecycle.

**Controllability** – The Kawasaki Smart Motor Controller provides high-speed digital control and can respond rapidly to changing conditions and user inputs. The control system runs continuously and allows the Staffa Smart/Smart+ Motor to rapidly change displacement under load and while rotating, in either motoring or pumping configuration. Control is achieved through measurement and thus is independent of operating conditions, and so the Staffa Smart Motor has the same performance envelope as the Staffa HPC motor platform on which it is built. Error responses can be programmed via the Kawasaki Smart Motor Controller to ensure the system operates safely under all conditions.

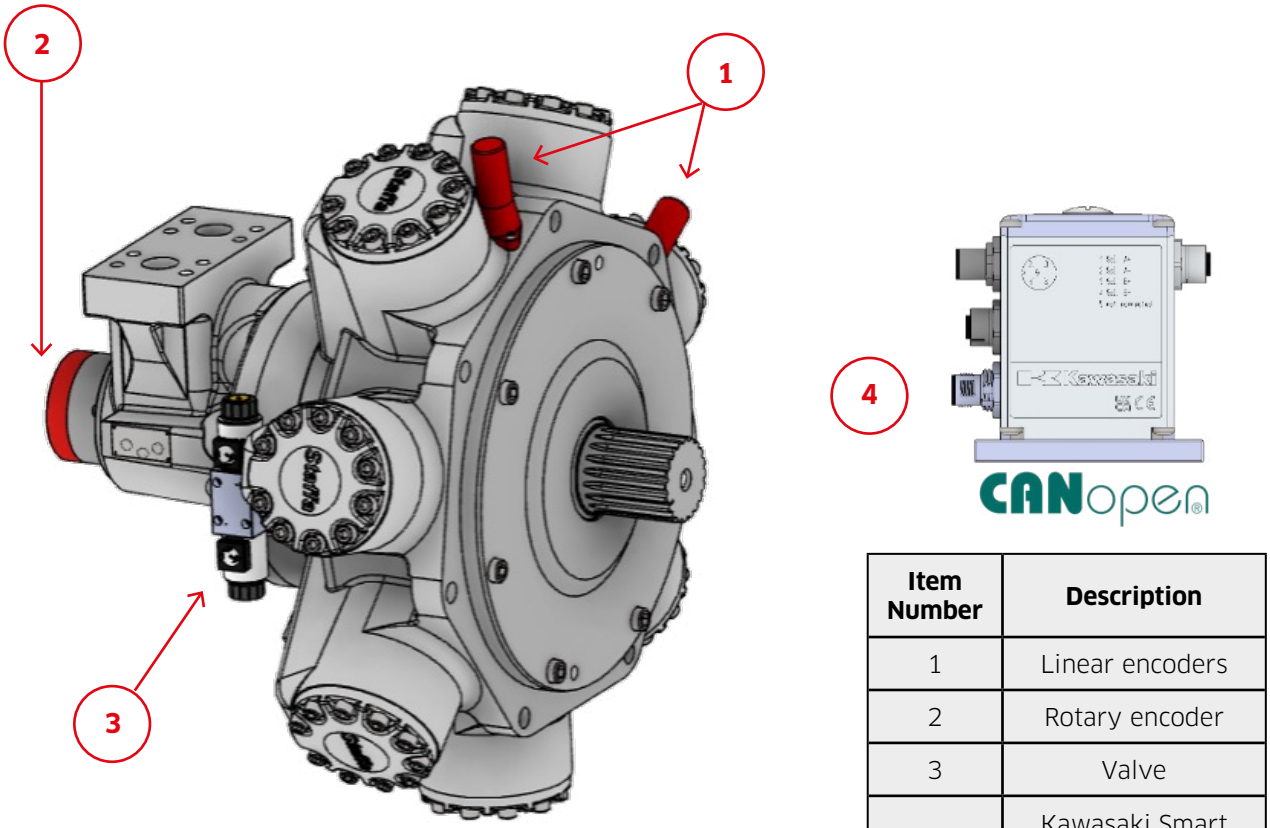
**Efficiency** – Improved efficiency may be achieved through two metrics: optimisation of motor displacement, and cycle time reduction. Optimisation: the Staffa Smart/Smart+ Motor can be set to run at any displacement which means it can be run at the most efficient setting for a given load. Combined with modern pump controllers, the Staffa Smart/Smart+ Motor is a key enabler of higher system efficiencies. Cycle time reduction: having the ability to change displacements dynamically reduces cycle times in many applications by eliminating the time required by other drives to stop and switch displacement modes.

**Connectivity** – A CANopen interface onboard the Kawasaki Smart Motor Controller means that all inputs, outputs and motor parameters are visible to other devices on a CANopen network. Parameters which are visible include instantaneous motor power, torque, differential pressure, speed, shaft position, measured displacement and mechanical efficiency.

## Features

- Infinitely variable displacement control
- Dynamic displacement shifting while motor is under load and turning
- Speed, direction and absolute shaft position sensing
- Control system which is independent of operating conditions
- Simple installation and set up
- Functions continuously between motoring and pumping conditions
- Datalogging facility
- Configurable emergency condition response
- Live torque and power figures calculated with respect to sensed motoring or pumping mode
- CANopen connectivity
- Live monitoring via USB link to PC
- Easy integration into modern electrical control systems

# 2 Overview- System Structure




| Item Number | Description |
|---|---|
| 1 | Linear encoders |
| 2 | Rotary encoder |
| 3 | Valve |
| 4 | Kawasaki Smart Motor Controller |

**Figure 2.1:** System structure

The Kawasaki Smart Motor Controller takes inputs from the two linear encoders and the rotary encoder to measure directly the instantaneous displacement of the motor. It compares this measurement (process value, PV), to the demand signal (set value, SV) to generate an error signal, **ε**. This error signal is processed by the controller to modulate the electric current being sent to the solenoids of the proportional valve, which either increases or decreases the motor's displacement towards the SV. Figure 2.2 shows this control scheme for the Staffa Smart Motor, and 2.3 for the Staffa Smart+ Motor

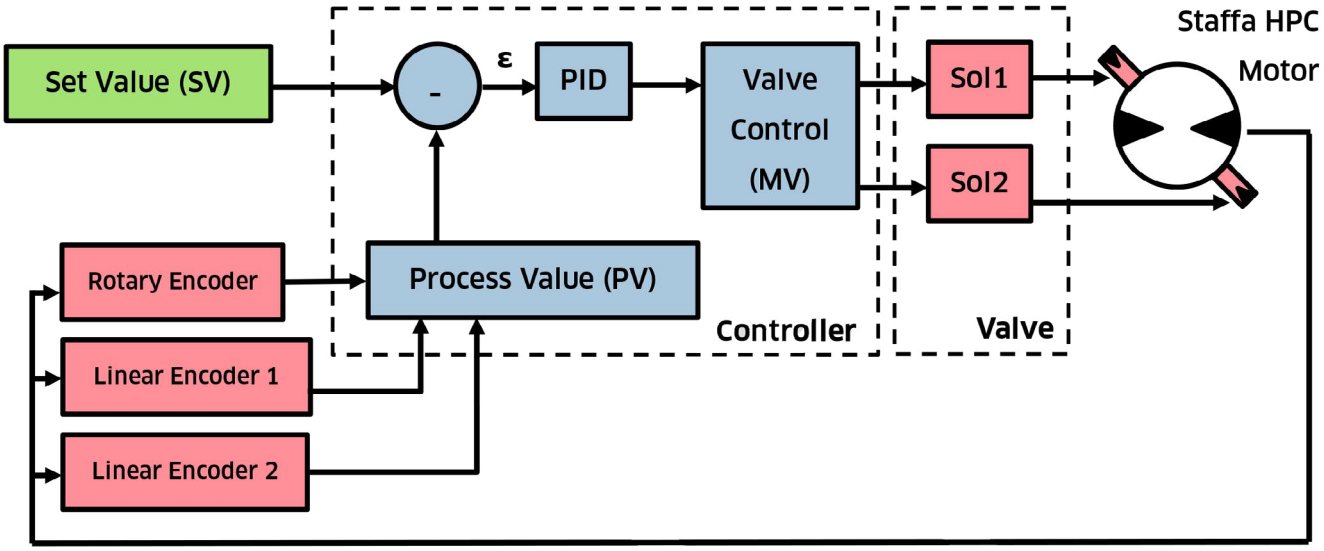



**Figure 2.2:** Closed-loop control schematic of control scheme implemented within the Staffa Smart Motor Controller

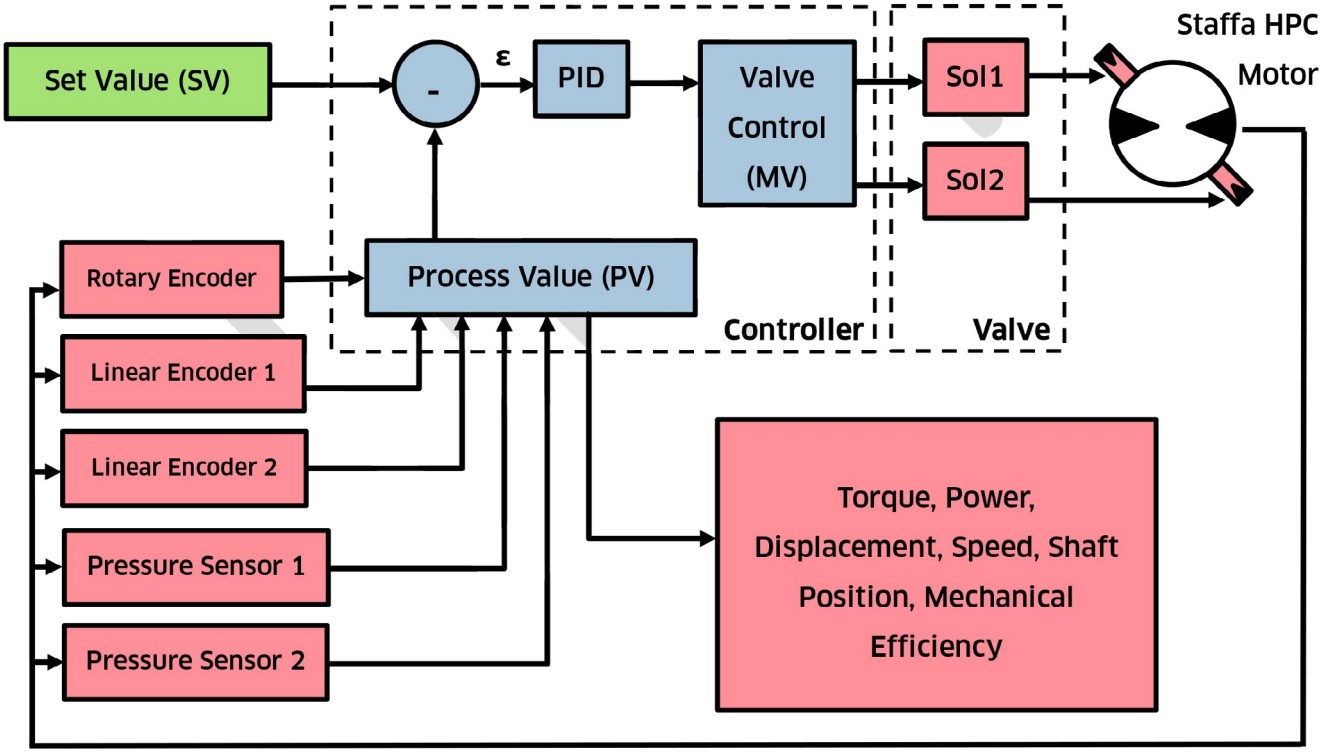



**Figure 2.3:** Closed-loop control schematic of control scheme implemented within the Kawasaki Smart Motor Controller and Staffa Smart+ Motor

# 3 Model Code

## HPCe325/S3/325/30/SFM4/**/P*****

1 2 3 4 5 6 7 8

| Model Code Item | Field Name | Model Code Options | Description |
|---|---|---|---|
| 1 | Smart Motor Version | HPCe | Smart version (see Section 5.1) |
| | | HPCi | Smart Plus (Smart+) version (see Section 5.2) |
| 2 | Frame Size | 325 | 7-cylinder configuration with maximum displacement of 5326cc/rev (325 cu. in.). |
| | | 200 | 5-cylinder configuration with maximum displacement of 3087cc/rev (188 cu. in.). |
| 3 | Shaft Designation | S3, etc. | See HPC datasheet for all output shaft options including DIN 5480 male/female, BS 3550 male/female, tapered and parallel-key designs. |
| 4 | High Displacement Code | *** | Cubic inches of required displacement. Standard displacements available in 5 cu. in. increments. |
| 5 | Low Displacement Code | *** | Cubic inches of required displacement. Standard displacements available in 5 cu. in. increments. |
| 6 | Hydraulic Connection configuration | SFM4 | SAE Code 62 Ø1.5” ports. |
| | | SM4 | Manifold mount through hole, Ø1.5” ports. |
| 7 | Design Series | ** | Assigned by Kawasaki. |
| 8 | Special Feature Suffix | P***** | See HPC motor datasheet for special feature options. |

**Table 3.1**

# 4 Applications

- Escort towing winch
- Anchor handling winch
- Auto-tensioning system
- Drilling/piling
- Test rig dynamometer
- Active heave compensation
- Crane winch

# 5 Options

## 5.1 Smart Version (HPCe)

The Staffa Smart Motor version provides the full displacement control functionality. The controller is set up with analogue and digital inputs and outputs. Without the CANopen connection, motor parameters such as torque, power, mechanical efficiency and speed are not available.

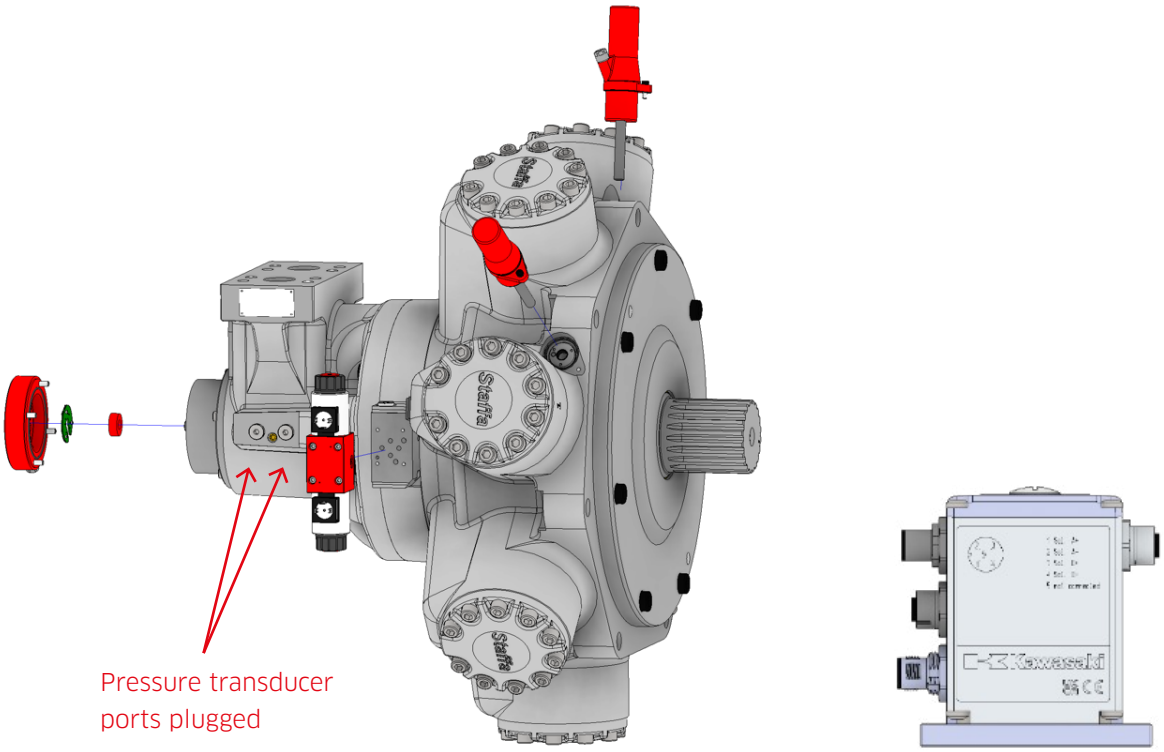



**Figure 5.1:** The Smart version of the Staffa Smart Motor

**In the box:**

- Staffa Smart Motor fitted with two linear encoders, one rotary encoder and double solenoid proportional valve.
- Staffa Smart Motor Controller. This is supplied with standard settings and may be configured using the parameterisation software to better suit each application or system (see Section 9).
- Two signal conditioners to convert SSI signals from the two linear encoders into analogue signals for the Staffa Smart Motor Controller. These are supplied with the correct settings from the factory.

**Inputs:**

| | |
|---|---|
| Displacement Preset | 0-5V when using internal stable 5VDC supply (or 4-20mA, 0-20mA, 0-10V) |
| Enable | Digital Signal (Dig. In 1) |
| Calibration Start | Digital Signal (Dig. In 3) |
| Error Reset | Digital Signal (Dig. In 4) |

**Table 5.1**

**Outputs:**

| | |
|---|---|
| Error Detected | Digital Signal (Dig. Out 1) |
| Calibration Complete | Digital Signal (Dig. Out 1) |

**Table 5.2**

## 5.2 **Smart+** Version (HPCi)

The Staffa Smart+ Motor version is supplied with two CANopen pressure transducers which the Staffa Smart Motor Controller can read via its CANopen interface. The pressure signals are used in conjunction with the encoder signals to generate live power and torque figures. Other devices may be connected to the CANopen network, and these figures are visible to them all, as are the pressure transducer signals. The CANopen connection also makes available other parameters to all devices on the network such as speed, shaft position and mechanical efficiency (see Section 8.2 CAN Objects).

The Staffa Smart Motor Controller can be master or slave on the CANopen network.

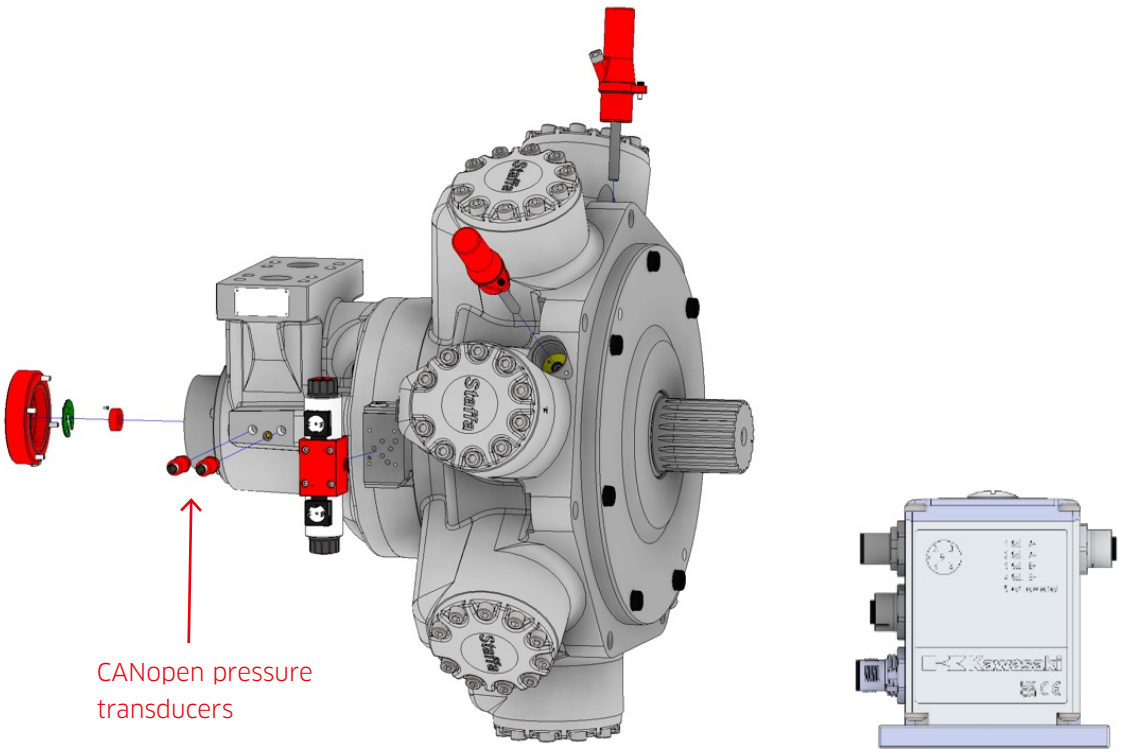



**Figure 5.2:** The Smart Plus version of the Staffa Smart Motor

Control signals may be transmitted to, and received from, the Staffa Smart Motor Controller via CANopen – see Section 7.2 for more details. Alternatively, control inputs and outputs may be supplied as described for the Smart Version in Section 5.1 via analogue and digital signals.

**In the box:**

- Staffa Smart Motor fitted with two linear encoders, one rotary encoder and double solenoid proportional valve.
- Staffa Smart Motor Controller. This is supplied with standard settings, but may be configured using the parameterisation software to better suit each application or system (see Section 9). Out of the box it will be set as node 1 for CANopen connections.
- Two signal conditioners to convert SSI signals from the two linear encoders into analogue signals for the Staffa Smart Motor Controller. These are supplied with the correct settings from the factory.
- Two CANopen pressure transducers, set up as nodes 2 and 3 out of the box.

# 6 Hydraulic Schematic

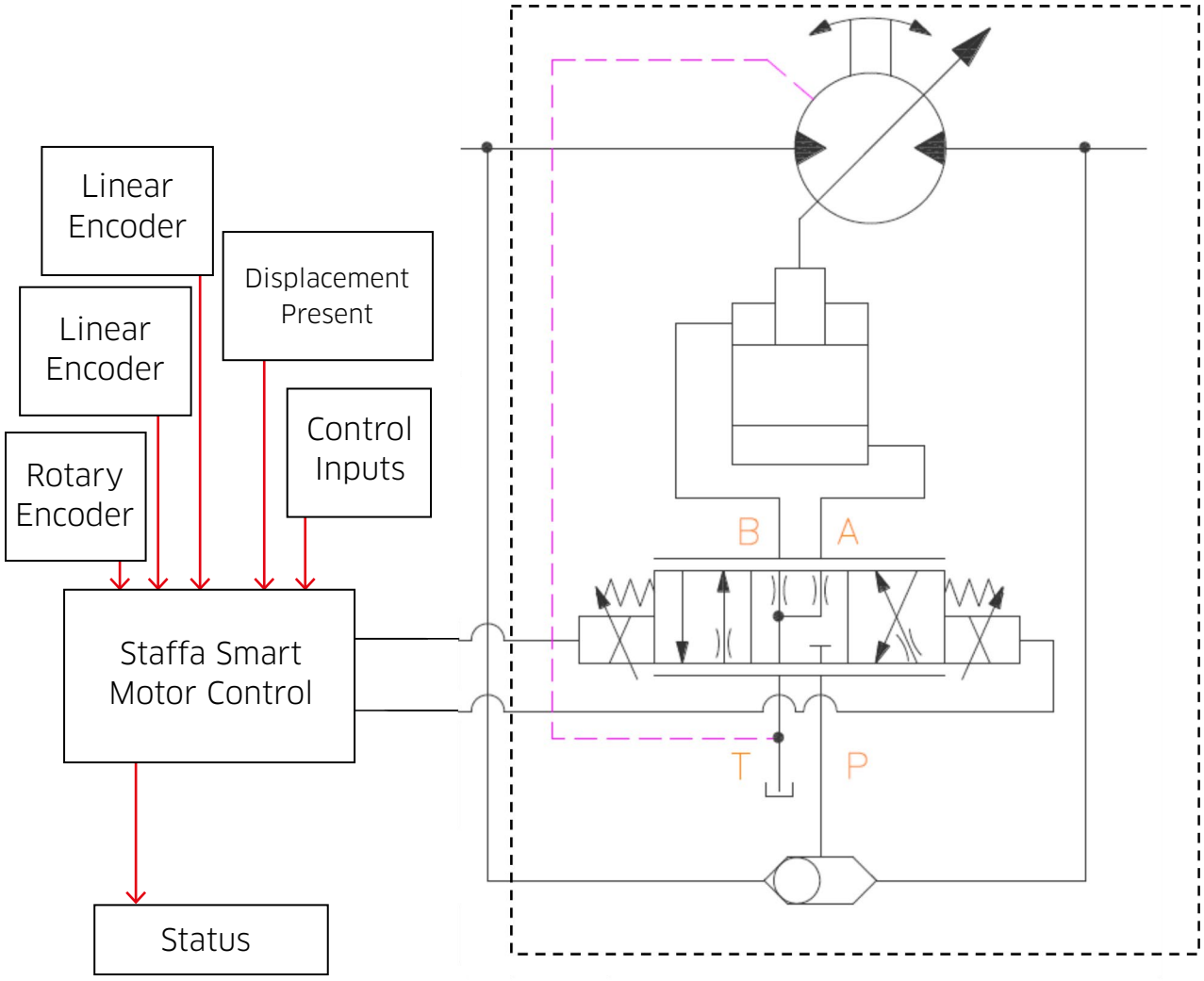



**Figure 6.1:** Staffa Smart Motor hydraulic schematic

# 7 Electrical Installation

## 7.1 Wiring

### 7.1.1 Analogue set up

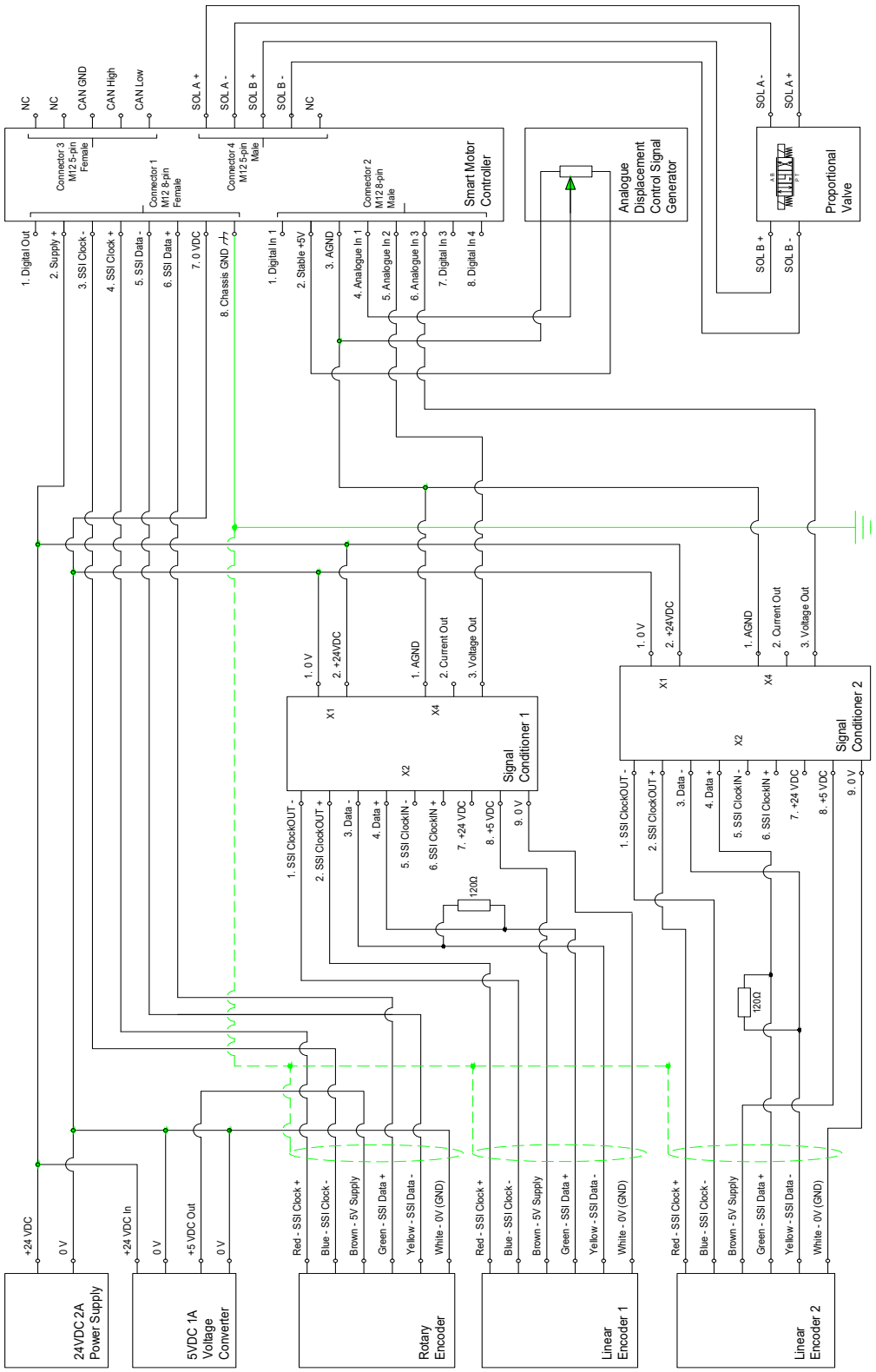



**Figure 7.1:** Wiring diagram for analogue set signal input

## 7.1.2 CANopen set up

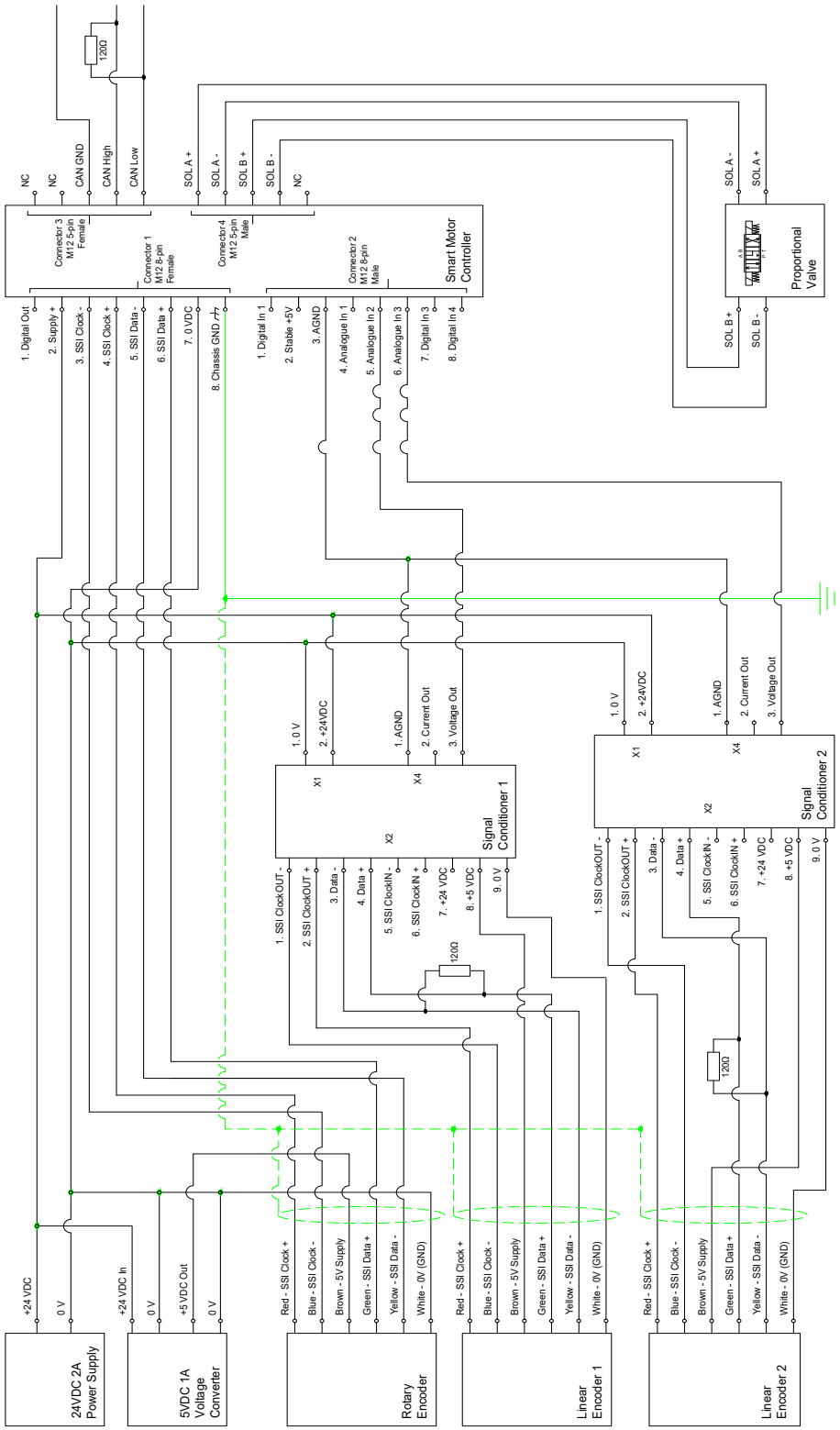



**Figure 7.2 :** Wiring diagram for CANopen set up

## 7.2 Connectors

### 7.2.1 Smart Motor Controller

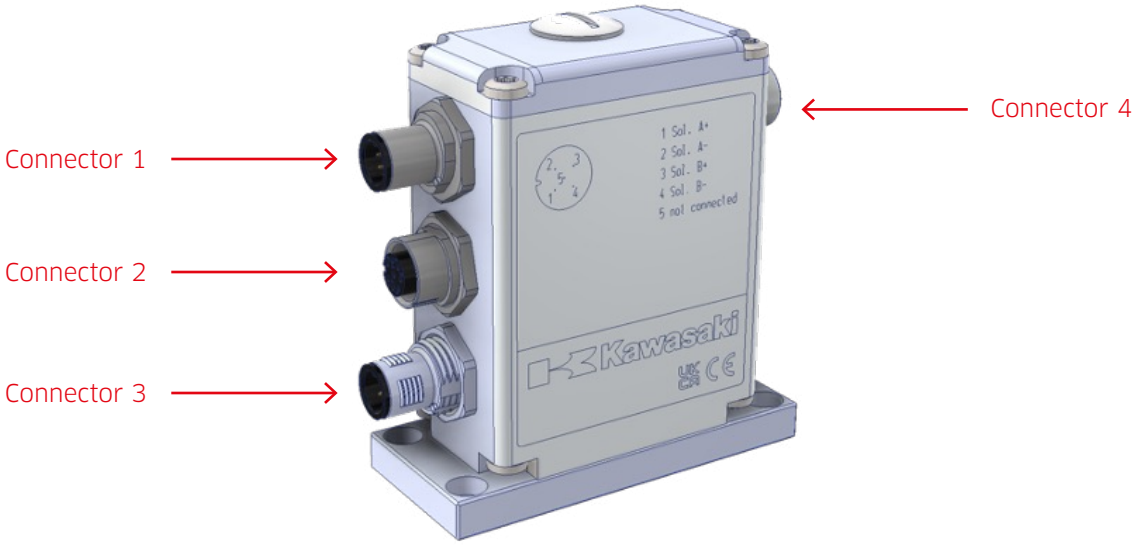



**Figure 7.3** Kawasaki Smart Motor Controller

**Connector 1:** Main/SSI – M12 8-pole male

| | |
|---|---|
| 1 | Dig. Out |
| 2 | V+ (24 VDC) |
| 3 | SSI Clock - |
| 4 | SSI Clock + |
| 5 | SSI Data - |
| 6 | SSI Data + |
| 7 | V- (0 VDC) |
| 8 | Chassis GND |

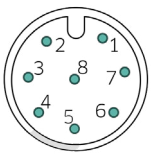



**Table 7.1**

**Connector 2:** Analogue/ Digital – M12 8-pole female

| | |
|---|---|
| 1 | Dig. In 1 |
| 2 | Stable +5VDC |
| 3 | AGND |
| 4 | Analogue In 1 |
| 5 | Analogue In 2 |
| 6 | Analogue In 3 |
| 7 | Dig. In 3 |
| 8 | Dig. In 4 |

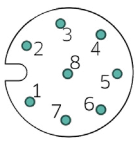



**Table 7.2**

## 7.2.1 Smart Motor Controller (cont)

**Connector 3:** CANopen – M12 5-pole male

| | |
|---|---|
| 1 | NC |
| 2 | NC |
| 3 | CAN GND |
| 4 | CAN High |
| 5 | CAN Low |

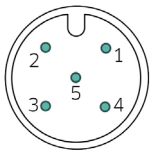



**Table 7.3**

**Connector 4:** Solenoids – M12 5-pole female

| | |
|---|---|
| 1 | SOL A+ |
| 2 | SOL A- |
| 3 | SOL B+ |
| 4 | SOL B- |
| 5 | NC |

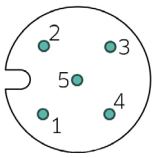



**Table 7.4**

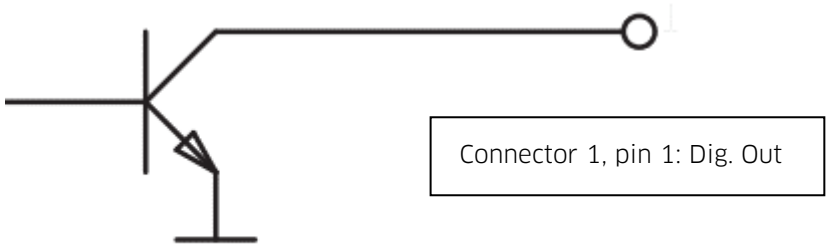



**Figure 7.2:** Digital Output pin (Connector 1, pin 1)

**NOTE:** The Digital Out pin on Connector 1 is an open collector output, and so requires a voltage source and load. When inactive, the impedance is high, and when the output is switched on, the pin is connected to the zero volts GND.

## 7.2.2 Linear Sensors

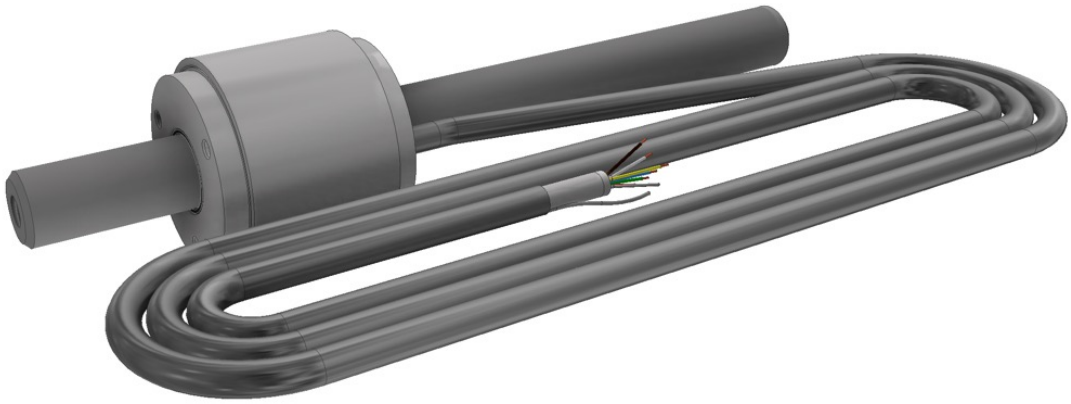


**Figure 7.3:** Staffa Smart/Smart+ Motor Linear Encoder

The linear sensors are supplied with 8-core 5m flying leads

| Wire Colour | Description |
|---|---|
| Outer shield | ⏚ |
| Inner shield | 0 VDC (GND) |
| Red | SSI Clock+ |
| Blue | SSI Clock- |
| Grey | - |
| Brown | V+ (5 VDC) |
| Green | SSI Data+ |
| Yellow | SSI Data- |
| Pink | - |
| White | 0 VDC (GND) |

**Table 7.5**

## 7.2.3 Rotary Encoder

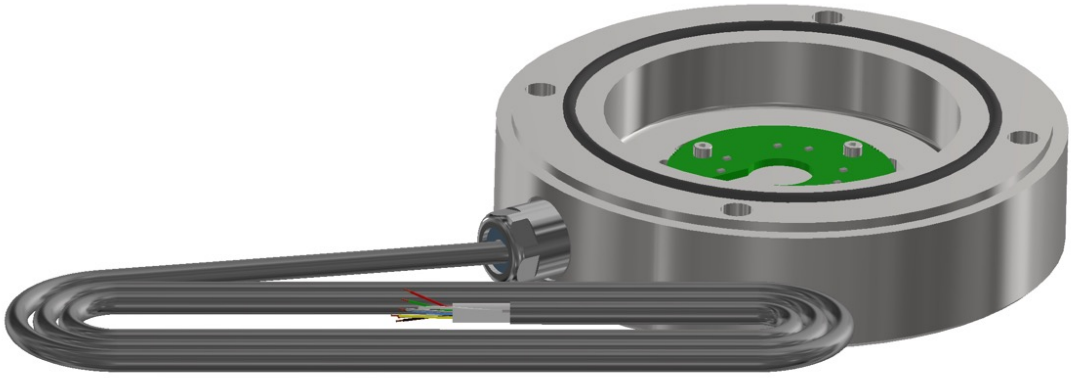


**Figure 7.4** Staffa Smart/Smart+ Motor Rotary Encoder

The rotary encoder is supplied with an 8-core 3m flying lead.

| Wire Colour | Description |
|---|---|
| Shield | ⏚ |
| Red | SSI Clock+ |
| Blue | SSI Clock- |
| Grey | - |
| Brown | 5 VDC Supply |
| Green | SSI Data+ |
| Yellow | SSI Data- |
| Pink | - |
| White | 0 VDC (GND)) |

**Table 7.6**

## 7.2.4 Pressure Transducers

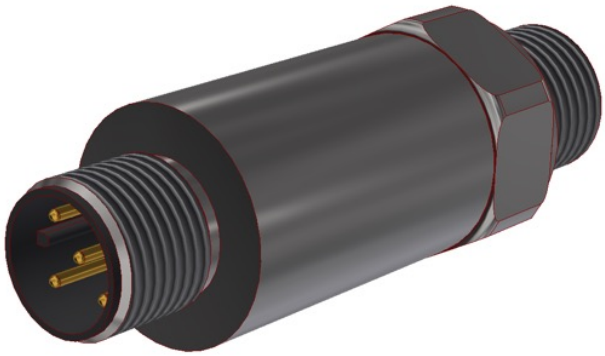


**Figure 7.5:** Staffa Smart/Smart+ Motor Pressure Transducer

M12 5-pole male, Mat. PA, IEC 61076-2-101

| | |
|---|---|
| 1 | ⏚ |
| 2 | V+ (24 VDC) |
| 3 | V- (0 VDC) |
| 4 | CAN High |
| 5 | CAN Low |

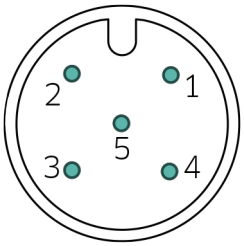



**Table 7.7**

## 7.2.5 Signal Conditioner

**Figure 7.8**

Screw terminals

| | | | |
|---|---|---|---|
| X1 | Power Supply | 1 | V- (0 VDC GND) |
| | | 2 | V+ (24 VDC) |
| X2 | Encoder Interface | 1 | SSI Clock- |
| | | 2 | SSI Clock+ |
| | | 3 | SSI Data- |
| | | 4 | SSI Data+ |
| | | 5 | - |
| | | 6 | - |
| | | 7 | - |
| | | 8 | 5 VDC Output |
| | | 9 | 0 VDC |
| X4 | Analogue Out | 1 | AGND |
| | | 2 | - |
| | | 3 | +/- 10 V |
| X6* | Control Outputs | 1 | Output Com V+ |
| | | 2 | Device Error |
| | | 3 | - |
| | | 4 | - |
| | | 5 | - |
| | | 6 | - |
| | | 7 | - |

**Table 7.8**

## 7.2.6 Smart Motor Proportional Valve – 2-pole Deutsch DT04

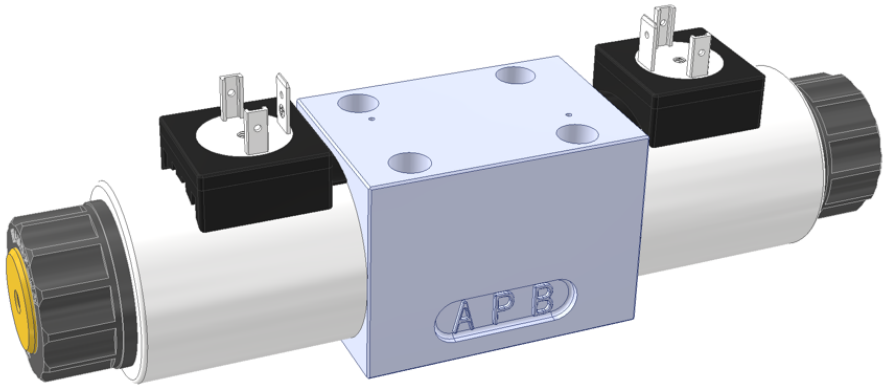



**Figure 7.9:** Staffa Smart/Smart+ Motor Proportional Valve

The valve is zinc-nickel coated and achieves 800h against the ISO 9227 salt spray test.

# 8 CANopen Control

## 8.1 EDS Files

The EDS files for the Kawasaki Smart Motor Controller and pressure transducers can be supplied by Kawasaki on request.
**Contact:** engineering@kawasakihydraulics.com / sales@kawasakihydraulics.com

## 8.2 CAN Objects

The following objects are read-only and can be mapped to a PDO using the PASO software (see Section 9).

| Index | Sub-index | Description | Data type | Unit | Smart | Smart+ |
|---|---|---|---|---|---|---|
| 0x2660 | 0 | Displacement | UINT16 | $cm^3/min$ | ✓ | ✓ |
| 0x2661 | 0 | Speed | INT16 | RPM x 10* | ✓ | ✓ |
| 0x2662 | 0 | Differential pressure | UINT16 | bar x 10* | | ✓ |
| 0x2663 | 0 | Torque | UINT16 | Nm | | ✓ |
| 0x2664 | 0 | Input power | UINT32 | W | | ✓ |
| 0x2665 | 0 | Mechanical efficiency | UINT16 | % x 1000* | | ✓ |
| 0x2666 | 0 | Total leakage | UINT32 | $cm^3/min$ | | ✓ |
| 0x2667 | 0 | Output power | UINT32 | W | ✓ | ✓ |
| 0x2668 | 0 | Shaft angular position | UINT16 | increment ($2^{14}$ per rev) | ✓ | ✓ |

**Table 8.1:** Output (read only) CAN objects of the Kawasaki Smart Motor Controller

*To transmit more accurate values, integers include first decimal place.
e.g. 225.6bar is transmitted as an integer of value 2256.

## 8.3 Status Word

| Index | Sub-index | Data type | Range |
|---|---|---|---|
| 0x6041 | 0 | UINT16 | See description below. |

The status word is bit coded as shown below and in Table 8.2.

| MSB | | | | | | | | LSB | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
| High byte | | | | | | | | Low byte | | | | | | | |

| Bit | Name | Description |
|---|---|---|
| 0 | Disable (D) | These bits determine the device conditions. Refer to the description of the device state machine. |
| 1 | Hold enable (H) | |
| 2 | Device mode active (M) | |
| 3 | Ready (R) | Is active if the controller is operated in local mode |
| 4 | Reserved | |
| 5 | Reserved | |
| 6 | Reserved | |
| 7 | Reserved | |
| 8 | Reserved | |
| 9 | Ramp running | The command value ramp is active |
| 10 | Calibration end | Kawasaki Smart Motor Controller calibration complete |
| 11 | Trailing window error | The trailing window error is active (closed-loop modes only) |
| 12 | Target window reached | The target window is reached (closed-loop modes only) |
| 13 | Reserved | |
| 14 | Pumping/Motoring Mode | 0 = motoring mode<br>1 = pumping mode<br>(Calculated by differential pressure and rotation directions.) |
| 15 | Profile is running | |

**Table 8.2**: Status word bit coding

## 8.4 Control Word

| Index | Sub-index | Data type | Range |
|---|---|---|---|
| 0x6040 | 0 | UINT16 | See description below. |

The status word is bit coded as shown below and in Table 8.3.

| MSB | | | | | | | | LSB | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
| High byte | | | | | | | | Low byte | | | | | | | |

| Bit | Name | Description |
|---|---|---|
| 0 | Disable (D) | These bits form the device control commands. Refer to the description of the device state machine. |
| 1 | Hold enable (H) | |
| 2 | Device mode active(M) | |
| 3 | Reset fault (R) | Resets an error/fault |
| 4 | Reserved | |
| 5 | Reserved | |
| 6 | Reserved | |
| 7 | Reserved | |
| 8 | Reserved | |
| 9 | Forward | |
| 10 | Backward | |
| 11 | Start calibration | Starts Smart Motor calibration mode |
| 12 | Fast speed | |
| 13 | Start | |
| 14 | Stop | |
| 15 | Single sequence | |

**Table 8.3:** Control word bit coding

## 8.5 Smart+ Pressure Transducers

The two pressure transducers are set up by Kawasaki as shown in **Table 8.4** below.

| Pressure Transducer | Motor Port | CANopen Node | CANopen PDO | CANopen COB-ID |
|---|---|---|---|---|
| PT1 | A | 2 | 1 | 0x182 |
| PT2 | B | 3 | 1 | 0x183 |

**Table 8.4:** Pressure transducer settings

The Kawasaki Smart Motor Controller must be set up with the following CANopen configuration in order to read the pressure transducer signals.

| Index | Sub-index | Description | Data Type | Unit |
|---|---|---|---|---|
| 0x2902 | 0 | Outlet Pressure (PT2) | UINT32 | bar/10 |
| 0x2905 | 0 | Inlet Pressure (PT1) | UINT32 | bar/10 |

**Table 8.5**: Kawasaki Smart Motor Controller CANopen objects (read-write) for pressure transducers

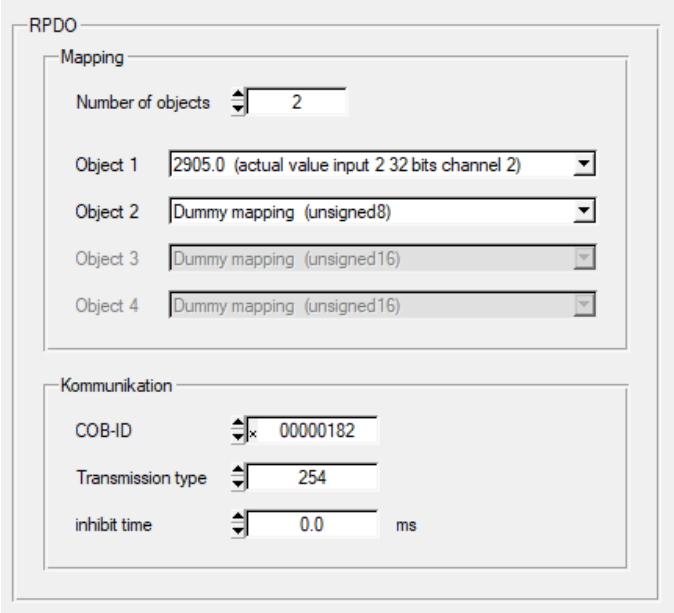



**Figure 8.1:** Kawasaki Smart Motor Controller CANopen PDO setting for PT1

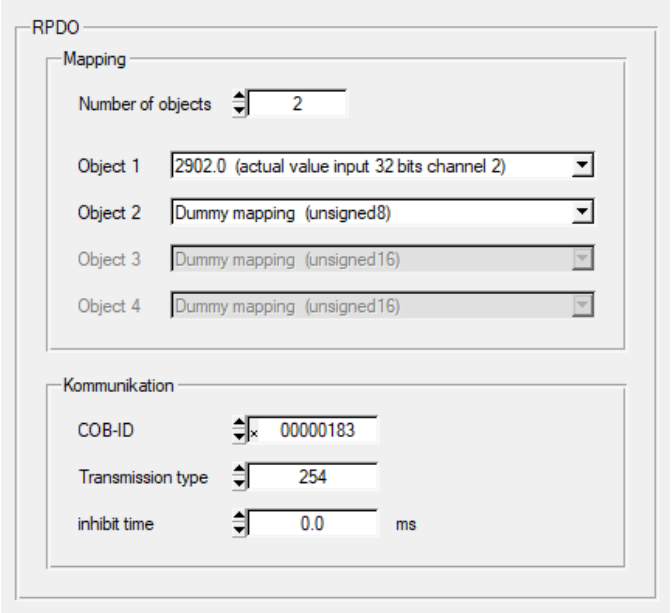



**Figure 8.2:** Kawasaki Smart Motor Controller CANopen PDO setting for PT2

# 9 Parameter Setting

## 9.1 Parameterisation Software

The parameters of the Kawasaki Smart Motor Controller can be modified to suit each application. It is recommended that Kawasaki Engineering or an accredited third party is consulted before attempting to change these settings.

**Contact:** engineering@kawasakihydraulics.com
sales@kawasakihydraulics.com

The settings which can be modified include:

- All CANopen settings including network speed, node numbers, PDOs, COB IDs, etc.
- Method of signal input/output from analogue/digital to CAN bus
- Signal scaling for input demand (SV) signal
- Error condition response
- PID constants and symmetry/asymmetry of the closed-loop digital controller
- Solenoid dither frequency and amplitude
- Minimum and maximum solenoid current limits

To make changes to any of these parameters, a computer running the parameterisation software must be connected to the Kawasaki Smart Motor Controller's USB port. To make changes to the CANopen parameters, the .eds file must be stored in the \eds folder location of the software's installation destination.

## 9.2 Calibration

The Kawasaki Smart Motor Controller is supplied in the calibrated condition from the factory and does not require calibration by the user. However, if a sensor is replaced or a new controller is fitted to the system, then it is necessary to run a new calibration routine. For this, the motor should be turning slowly (<5RPM) while one of the following sequences is followed:

**CANopen set up (Smart+ version only):**

1. Disable the Smart+ Motor Controller by setting the control word to 0x0
2. Start the calibration routine by setting the control word's bit 11 to 1 (0x0800)
3. When the calibration routine has completed, the status word's bit 10 will switch on (0x0400). The calibration routine will take approximately 10 full turns of the motor shaft to complete.
4. Enable the controller by setting the control word to 0x0007

**Analogue set up (Smart/Smart+):**

1. Disable the Smart Motor Controller by setting the allocated digital input, "Dig. Input enable", to OFF
2. Start the calibration routine by setting the allocated digital input for "Dig. Input start" to ON (the default setting for "Dig. Input start" is Dig. In 3)
3. Wait for the completion signal on the allocated digital output, "Dig. Output end".
4. Switch the calibration routine digital input, "Dig. In start", to OFF and enable the controller by switching the allocated digital input, "Dig. Input enable" to ON.

During the calibration routine, the following parameters are automatically determined:
- Min/max interface of both linear sensors
- Min/max reference of both linear sensors
- Rotary encoder offset angle

All determined parameters are stored automatically on the controller when the calibration routine is successfully completed.

## 9.3 Input Parameter Setting

By clicking on the “Command Scaling” button, the dialogue box below will be displayed. Here, the command value, SV, may be assigned to either the CANopen object or an analogue channel. To select the method of communication for the SV, change the selection in the “Command value mode” drop-down box.

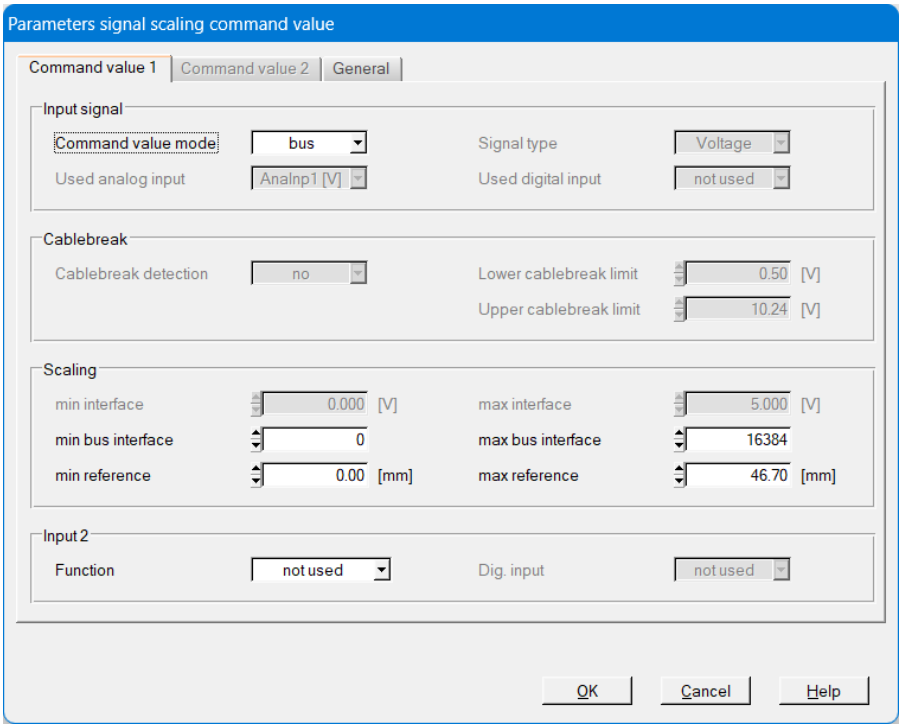



**Figure 9.1:** Command signal scaling window for CANopen set up of SV signal

If an analogue signal is to be used, a voltage or current may be selected and then scaled. The “minimum reference” and “maximum reference” fields should be set according to the values in Table 9.1.

| Staffa Motor Frame Size | Min Reference (mm) | Max Reference (mm) |
|---|---|---|
| HPC200 | 0 | 38.10 |
| HPC325 | 0 | 46.70 |

**Table 9.1:** Minimum and maximum reference values for input signal (SV) scaling

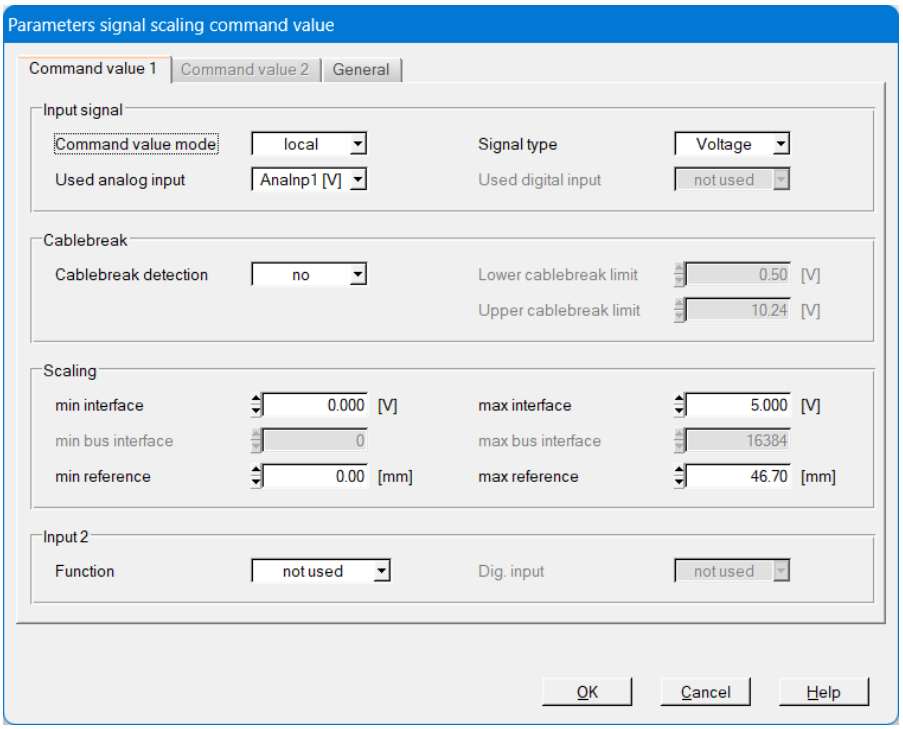



**Figure 9.2:** Command signal scaling window for analogue set up of SV signal

# 9.4 CANopen Parameter Setting

## 9.4.1 Fieldbus > Info

The CANopen bus speed and the Kawasaki Smart Motor Controller's Node-ID can be set in the External Bus dialogue box. By default, the bus speed is 500kbps.

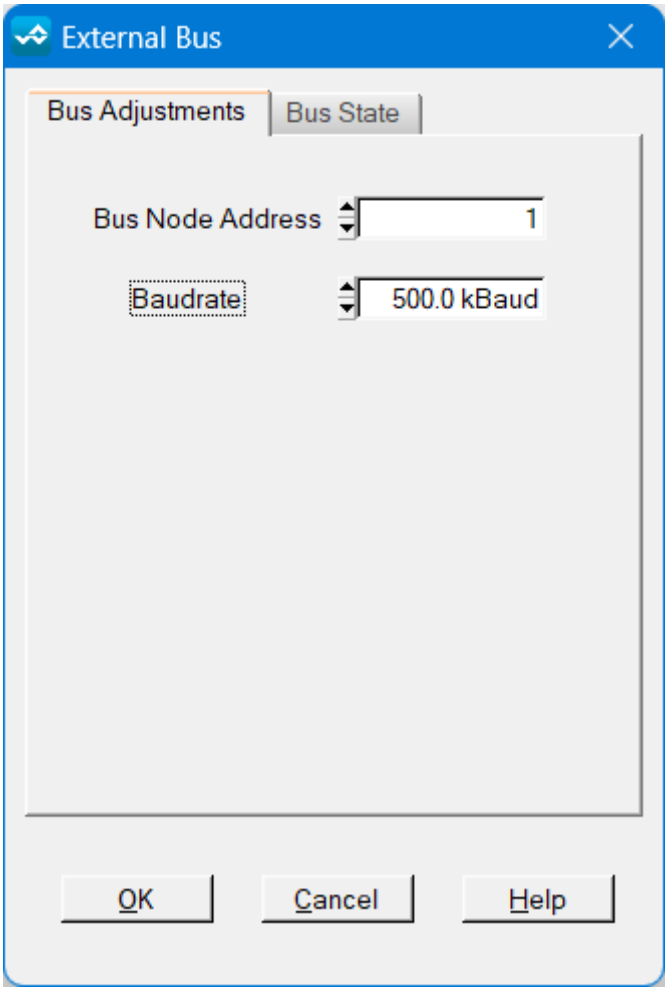



**Figure 9.3:** CANopen bus settings showing default settings of Node 1 and 500kbps network speed

## 9.4.2 Fieldbus > Parameters

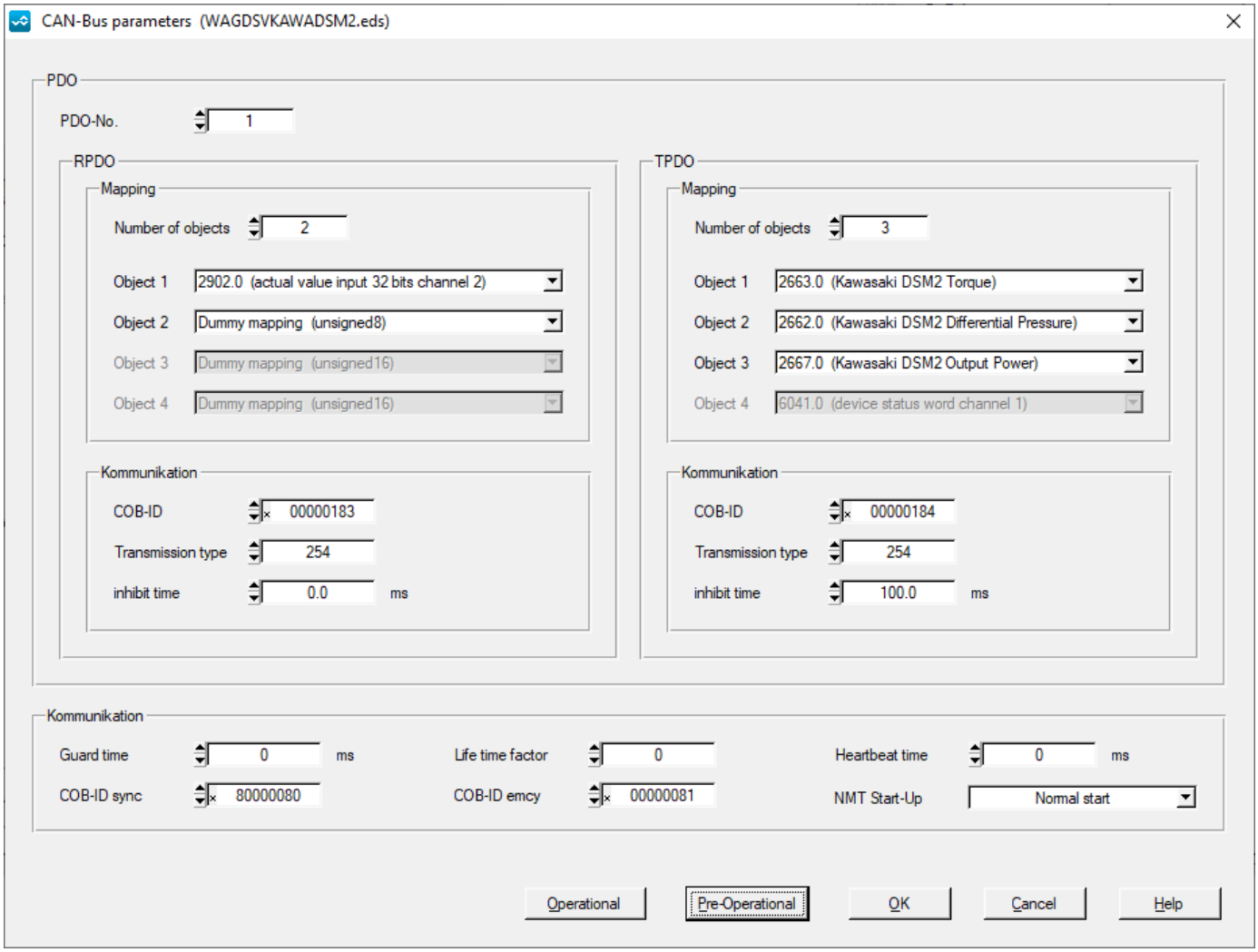



**Figure 9.4:** CANopen parameter setting window showing PDO1 default settings

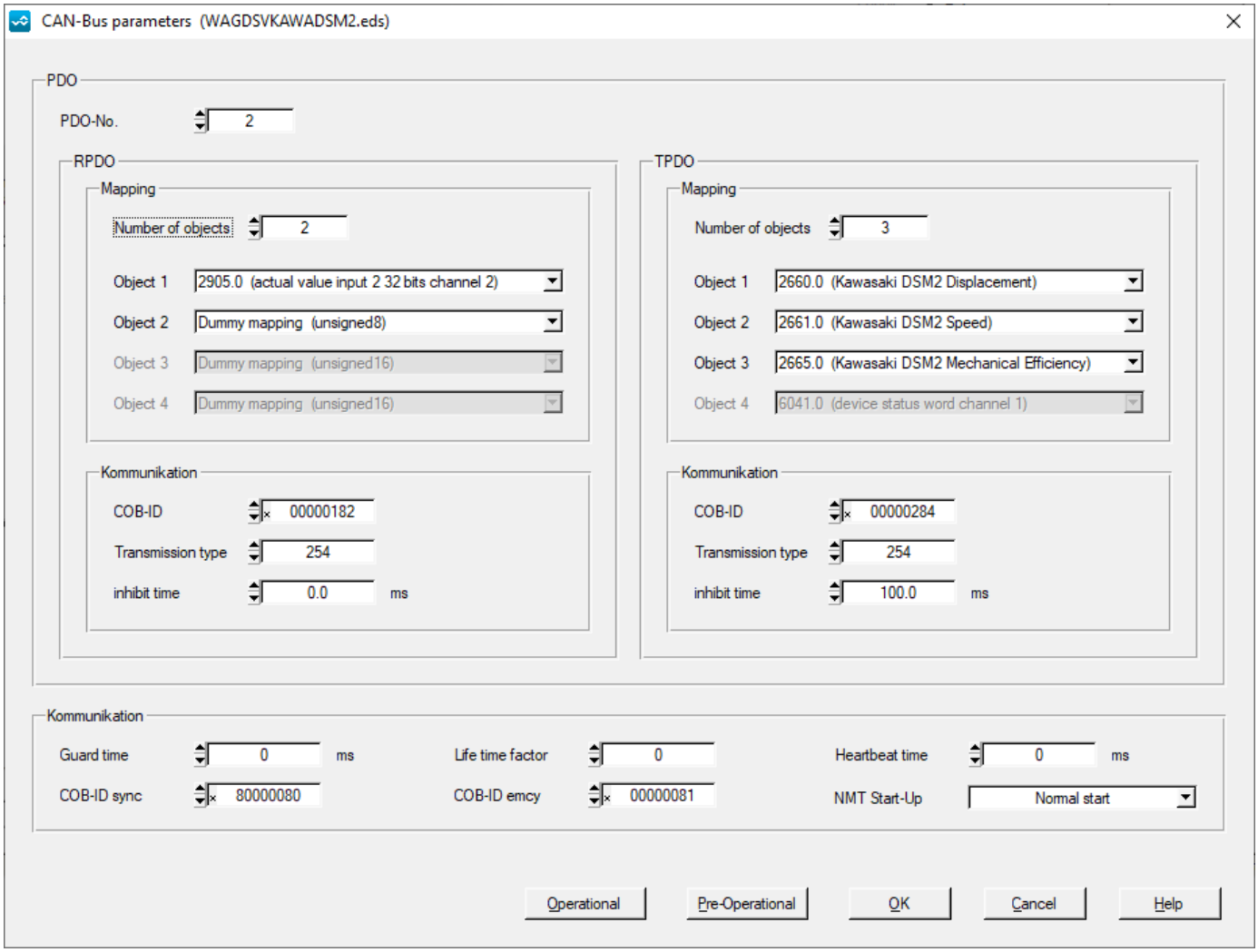



**Figure 9.5:** CANopen parameter setting window showing PDO2 default settings

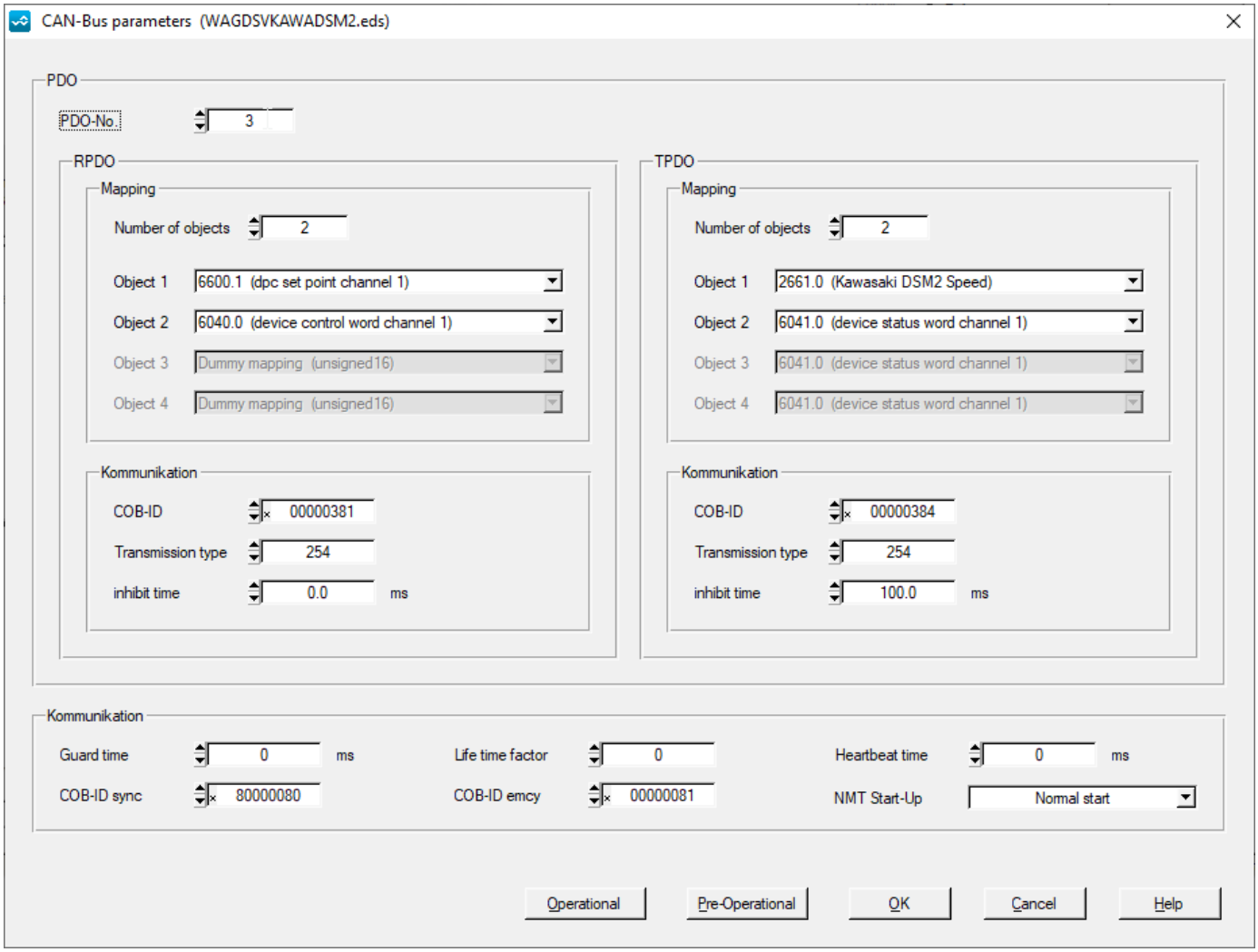



**Figure 9.6:** CANopen parameter setting window showing PDO3 default settings

# 10 Operation

## 10.1 Performance

[See HPC datasheet for full performance tables.]

## 10.2 Motoring and pumping

The Kawasaki Smart Motor will precisely control the motor's displacement whether it is running as a motor, or being driven by a load (pumping). The Smart+ model will detect the mode of operation, and adjust the efficiency, torque and power calculations accordingly. This means that the figures which are transmitted on the CANopen variables 0x2665 and 0x2667 can be used with confidence.

Fig. 10.1 shows how the Smart+ motor detects whether the Kawasaki Smart Motor is running as a pump or as a motor. The differential pressure is obtained by subtracting the reading from PT2 from PT1's value. NOTE: if the anti-clockwise feature is selected for the motor, no change to the position of the pressure transducers is required. PT1 should still be connected to Port A and PT2 to Port B.

Note: if the anti-clockwise feature is selected for the motor, no change to the position of the pressure transducers is required. PT1 should still be connected to Port A and PT2 to Port B.

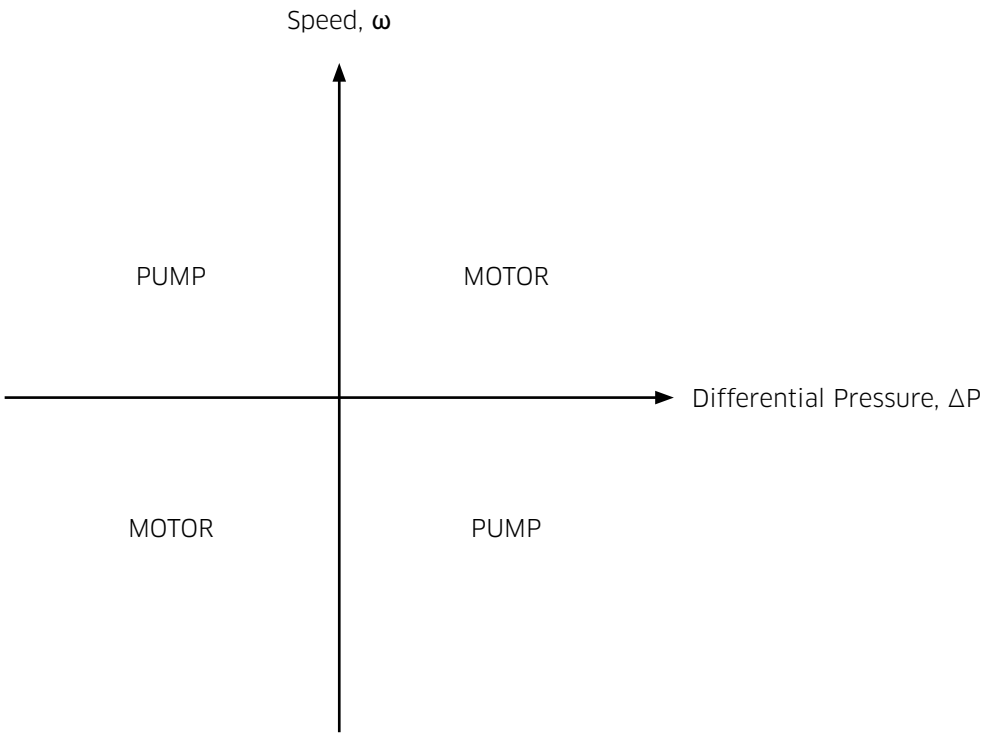
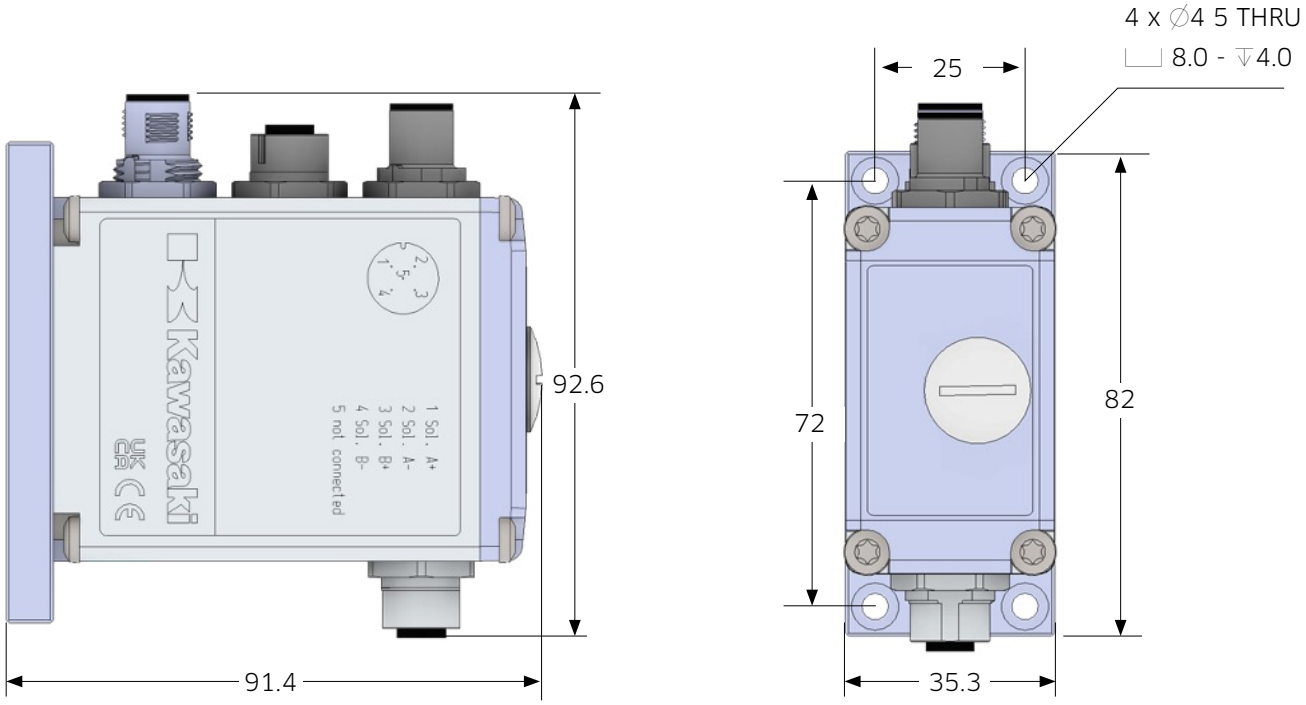



**Figure 10.1**

# 11 Installation Dimensions

## 11.1 Kawasaki Smart Motor Controller




The pin-out of the Kawasaki Smart Motor Controller is etched onto the sides of the unit.

**Figure 11.1**

## 11.2 Signal Conditioner Unit

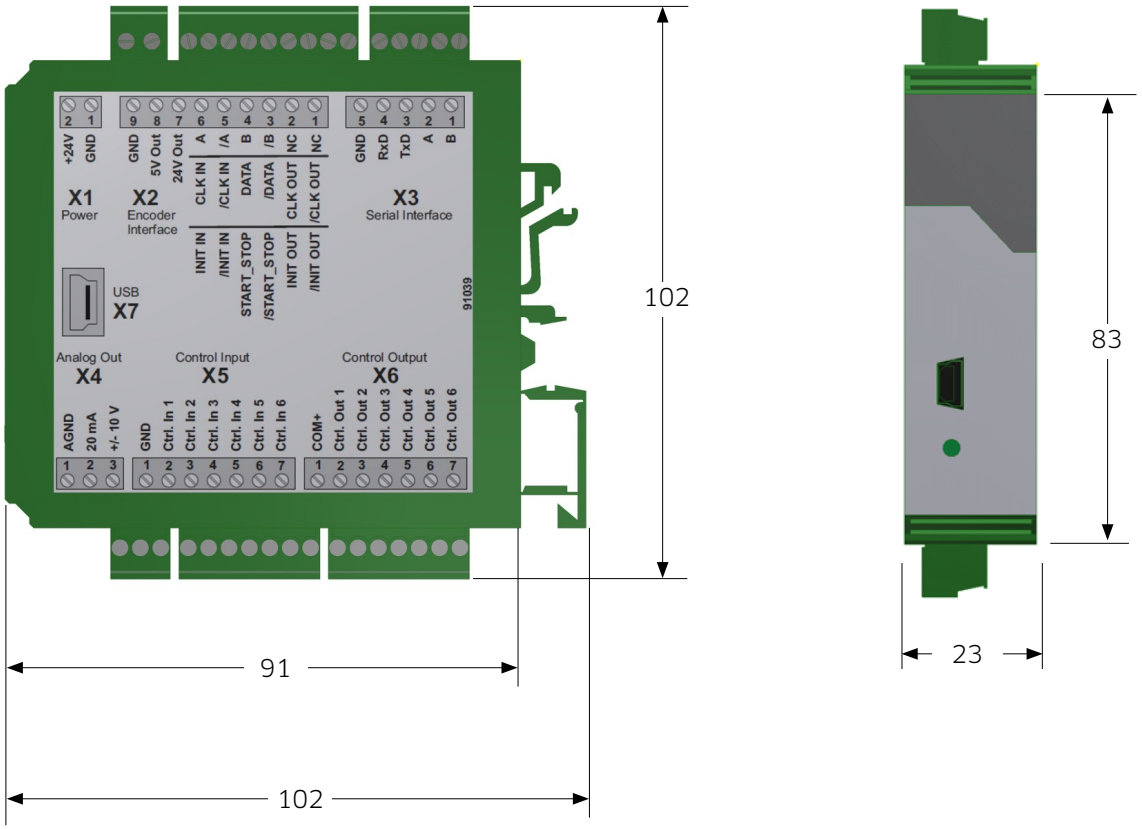



**Figure 11.2**

## 11.3 Staffa Smart Motor

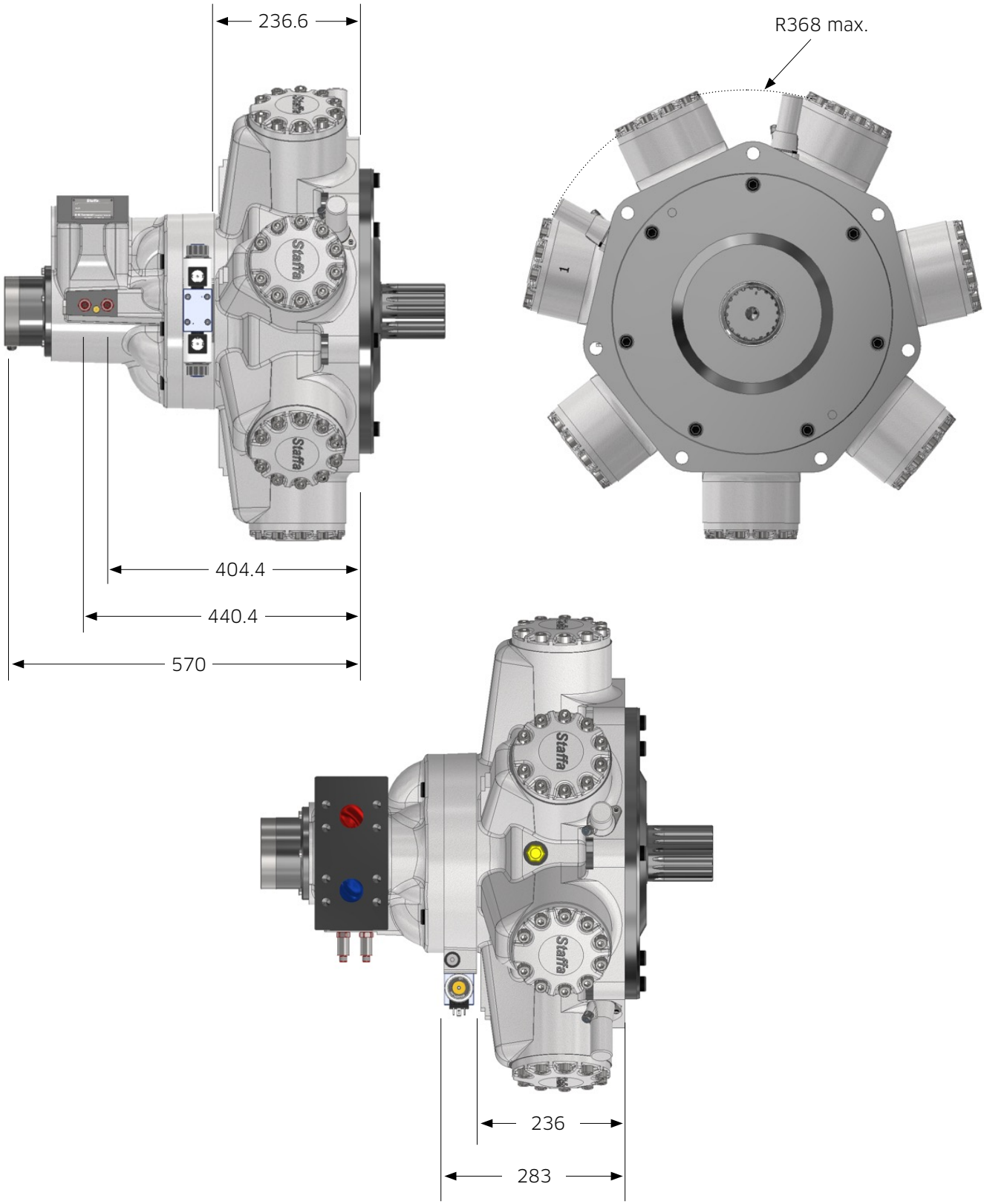



**Figure 11.3**

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