HUMMINGBIRD
SENSING TECHNOLOGY

Paracube® Sprint

Digital Paramagnetic Oxygen Sensor Module

Instruction Manual

Product Part Numbers: 00501/7XX series refer to table 7 for details.

Manual Part Number: 00501001A
Revision: 2
Language: UK English

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HUMMINGBIRD SENSING TECHNOLOGY

WARNINGS, CAUTIONS AND NOTES:

This publication includes WARNINGS, CAUTIONS and NOTES which provide, where appropriate, information relating to the following:

WARNINGS: Hazards that may result in personal injury or death (coloured red).

CAUTIONS: Hazards that will result in equipment or property damage.

NOTES: Alerts the user to pertinent facts and conditions.

WARNING - (USE):

As the final conditions of use are outside Servomex's control, it is the responsibility of the equipment designer or manufacturer to ensure that the sensor is integrated in accordance with any regional standards or regulations governing the final application.

The sensor should not be relied upon as a single source of safety monitoring unless expressly permitted within the regional standards or regulations governing the final application.

NOTE:

For safety reasons any sensor returned to Servomex must be accompanied by the Decontamination Clearance Certificate contained in this manual. Unless the cell is accompanied by this certificate, Servomex reserves the right to refuse to undertake any examination of the product.

Apply appropriate anti-static handling procedures. Sensor returns must be packed in the original packing material to prevent damage in transit.

NOTE:

The information in this document is subject to change without notice.

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UK Legislation

Health and Safety at Work Act 1974
Control of Substances Hazardous to Health Regulations 2002 (as amended)
Ionising Regulations 1999

Important Notice

Servomex ensure that all products despatched to customers have been suitably purged and cleaned prior to packaging, so that no hazards from the use of factory calibration gases or liquids will be present.

No item returned to Servomex or its representatives, for any reason whatsoever, will be accepted unless accompanied by a copy of the following form fully completed and signed by a responsible person. This is a requirement to comply with the above listed legislation and to ensure the safety of the employees of Servomex and its representatives.

…………………………………………………………………………………………

Please tick one of the following sections as applicable to your equipment.

Decontamination Statement. ☐

It is hereby certified that a suitable and sufficient decontamination process has been carried out and we have taken reasonable action to ensure that the returned equipment described below will be free of potential toxic, corrosive, irritant, flammable, radioactive or biological hazards and is safe to be handled, unpacked, examined and worked upon by Servomex employees and its representatives.

Please give detail of decontamination process used:-______________________________
____

Decontamination Clearance Certificate. ☐

It is hereby certified that the equipment described below has never been exposed to any potential toxic, corrosive, irritant, flammable, radioactive or biological hazards, therefore it is reasonably expected that it should be safe for Servomex employees and its representatives to handle, unpack, examine and work upon the equipment described below.

Equipment ______________________
____

Serial no ______________________

Reason for return ____________________
____
____
____
____
____

Company ______________________
____

Signature ______________________

Print name ______________________

Position ______________________

Date ______________________

Company seal or stamp:-

Form: 5000/2 issue2

HUMMINGBIRD SENSING TECHNOLOGY

1: Introduction

The Paracube® Sprint represents the latest generation of Servomex's paramagnetic sensing technology. The sensor takes advantage of recent technological advances allowing a performance only previously available from sensors of much greater size and cost.

The sensor offers the OEM true flexibility in both mechanical and communication interfaces incorporating Servomex's world renowned paramagnetic technology (described in section 2 of this manual) which has been designed into many OEM products where reliability, long life and performance are major considerations.

Servomex's non-depleting paramagnetic technology ensures consistent performance over time with added cost-of-ownership benefits. The selectivity of the measurement to oxygen means there is no interference from other respiratory gases. The sensor provides a stable oxygen measurement, which is inherently linear requiring only two reference gases to perform a full calibration. There is no requirement for a reference gas during operation.

Note - No. 1
This Paracube® Sprint manual details the operation and installation of the Digital variants only.
A full list of the digital variants for the Paracube® Sprint is detailed in section 6.1. The manual detailing the Analogue variants can be ordered under part number 00501009A.

2: Servomex Paramagnetic Measurement Principle

The sensor utilises the paramagnetic susceptibility of oxygen, a physical property which distinguishes oxygen from most other common gases.

The sensor incorporates two nitrogen-filled glass spheres mounted on a strong, noble metal taut-band suspension. This assembly, termed the “Suspension Assembly” is suspended in a symmetrical non-uniform magnetic field. When the surrounding gas contains paramagnetic oxygen, the glass spheres are pushed further away from the strongest part of the magnetic field. The strength of the torque acting on the suspension is proportional to the oxygen content of the surrounding gases.

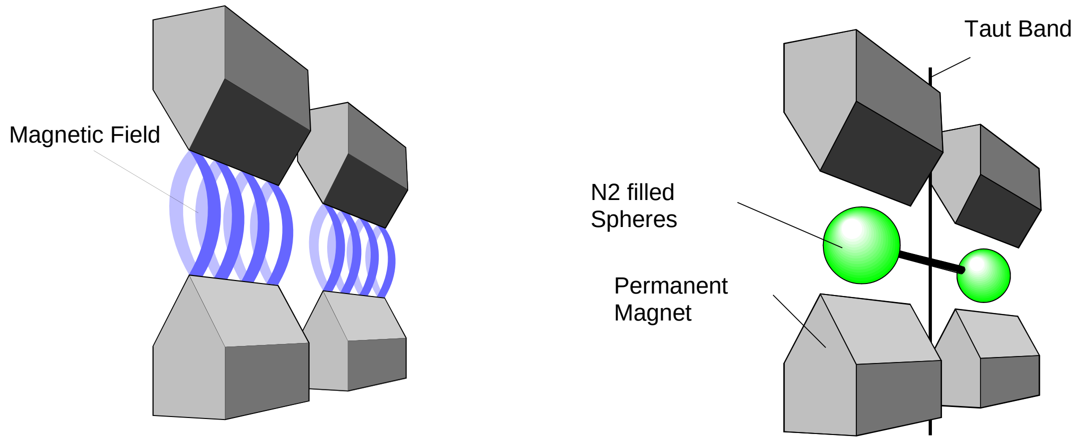

Fig.1

The measuring system is "null-balanced". The 'zero' position of the suspension assembly, as measured in nitrogen, is sensed by a differential photo-sensor assembly that receives light reflected from a mirror attached to the suspension assembly. The output from the photo-sensor is processed and then fed back to a coil wound around the suspension assembly to achieve a “Null Balanced” position. This feedback achieves two objectives:

When oxygen is introduced to the cell, the torque acting upon the suspension assembly is balanced by a restoring torque due to the feedback current in the coil. The feedback current is directly proportional to the volume magnetic susceptibility of the sample gas and hence, after calibration, to the partial pressure of oxygen in the sample. A voltage output is derived which is proportional to the feedback current.

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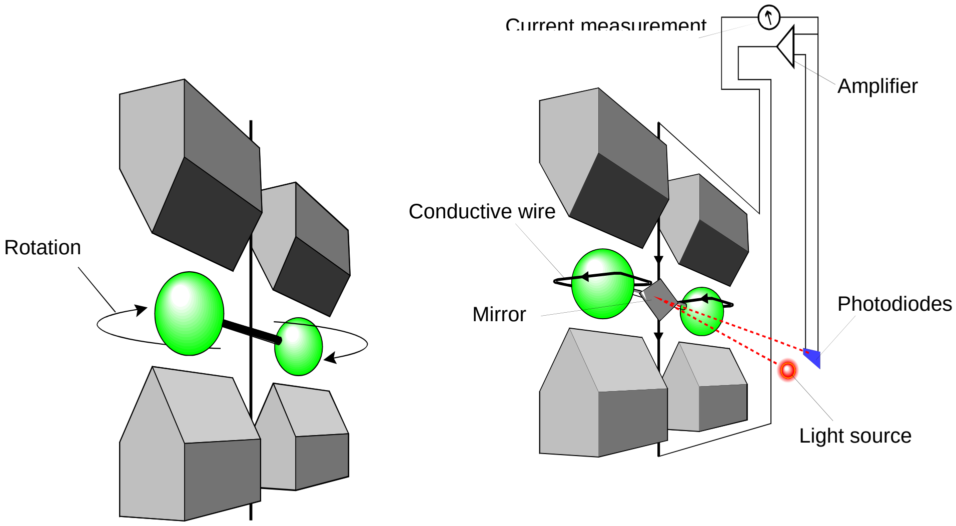


Fig.2

In addition, the electromagnetic feedback stabilises the suspension (heavily damping oscillations) thus making it resilient to shock and vibration.

3: Product Specification

3.1 Performance Specification (under constant conditions)

This specification applies when the sensor has been calibrated using standard gas values of N_2 and 100% O_2 using the calibration procedure described in section 5. Unless otherwise stated, the performance figures quoted are derived from two standard deviation analysis. Where marked (†) testing has been conducted in accordance with the requirements of IEC 61207-1 1994

Operating Range
0 to 100% O_2 with over range capability -15% O_2 to +200% O_2

Intrinsic Error†
<±0.2% O_2

Linearity†
<±0.2% O_2

Repeatability†
<±0.2% O_2

Signal Noise (peak to peak) †
<0.2% O_2

Zero Stability (permanent drift from calibration value) †
<±0.4% O_2 for first 24 hours
<±0.2% O2 for the subsequent week (additional)
<±0.2% O_2 per month thereafter (additional)

Temperature Coefficient
Zero: <±0.5% O_2 / 10^oC
Span: <±0.5% of O_2 reading / 10^oC

Response Time

Rise Time (t_{10} - t_{90})

Gas Exchange	Sample Flow Rate	Response Time
16% - 21%O_2	50mL.min^{-1}	1,150 ms
	120mL.min^{-1}	395 ms
	190mL.min^{-1}	230 ms
	250mL.min^{-1}	170 ms
21% - 100%O_2	50mL.min^{-1}	1,300 ms
	120mL.min^{-1}	560 ms
	190mL.min^{-1}	370 ms
	250mL.min^{-1}	280 ms

Fall Time (t_{10} - t_{90})

Gas Exchange	Sample Flow Rate	Response Time
21% - 16%O_2	50mL.min^{-1}	1,150 ms
	120mL.min^{-1}	395 ms
	190mL.min^{-1}	210 ms
	250mL.min^{-1}	160 ms
100% - 21%O_2	50mL.min^{-1}	1,300 ms
	120mL.min^{-1}	560 ms
	190mL.min^{-1}	300 ms
	250mL.min^{-1}	190 ms

Flow Error

<±0.3% for 10ml/min change in flow rate within the operating flow range (50 to 250 ml/min)

Pressure Range

±33kPag (±5sig), operating
±66kPag (±10psig), proof
±100kPag (±15psig), failure

Tilt

<±0.5% O_2 equivalent for 15° change in orientation from the calibration point

Time to Valid Reading
Time to valid output (from power up when within environmental spec) <6 seconds
Time to status output (from power up when outside environmental spec) < 6seconds

Pressure Compensation
<0.8% of reading for 20kPag (±3psig), change from calibration point.

3.2 Mechanical Specification

Dimensions (W X D X H)
The mechanical dimensions of all available sensor variants are detailed in appendix 7.1 and 7.2 of this document.

Weight
~70 grams (~2.47 ounces)

Pneumatic Leakage
$3x10^{-4}$ mbar.L.sec^{-1} (~$3x10^{-4}$ SCCS)

Operational flow rate
50 to 250 ml/min, Max purge at 300ml/min

Materials in Contact with Sample Gas
316 stainless steel
Borosilicate glass
Polyphenylene sulphide (PPS) with PTFE / glass filler
Platinum iridium alloy
Nickel
Fluorocarbon elastomer -FPM (Viton)
Krytox GPL205 grease

3.3 External Power Supply Specification

+5V dc ±5%, a supply supervisor inhibits operation when the PSU is below 4.75V.
Ripple and noise <0.1V Pk to Pk.
Current consumption: 5V supply rail = 70mA typical 100mA max.
A change of ±0.25V in supply Voltage results in a change of less than ±0.1% in oxygen concentration.

3.4 Environmental Specification

Sample Gas Condition
Dry, non-corrosive, non-flammable gas, free of entrained oil, less than 3 micron particulates, non-condensing, dew point 10°C below the sensor operating temperature.

Pressure Effect
The oxygen output will change in direct proportion to the barometric pressure unless pressure compensation is enabled (see variant options, table 7).

Pressure compensation can be toggled via the serial command !Pn↵ , where n = 0 or 1 for disabled or enabled respectively (see table 6).

Operating Temperature
5°C to 50°C (41°F to 122°F).

Storage Temperature (non-condensing conditions)
-30°C to +70°C (-22°F to 158°F).

Storage Pressure
10kPa – 200kPa (1.5psi - 30psi)

Thermal Time Constant
15 minutes. Time required for the O_2 signal to reach 66% of final reading when the sensor has been subjected to a 20°C step change in ambient temperature.

Ambient Humidity
0 to 95% RH.

Altitude Range (operating)
-500m to +5000m (-1540ft to +15400ft)

Shock and Vibration
Meets the requirements of BS EN 60068-2-6:1996 (IEC 68-2-6),
BS EN 600-2-27:1993 (IEC 68-2-27) and IEC 68-2-34. Details of these requirements are given in Appendix 7.3.

Soft magnetic material
A change in the reading of <0.1% O_2 will occur when a soft magnetic material is brought within 10mm of the sensor body.

Interference Effects

The paramagnetic effect of common background gases at 20^{o}C, for 100% concentration is shown below:

Interfering Gas	Interference Effect (100% Interferent) (% O_2)
N_2O	-0.20
CO_2	-0.26
H_2O	-0.03
Methane	-0.16
CO	0.06
Helium	0.29
NO	42.56
NO_2	5.00

A comprehensive list detailing the effect of other background gases is outlined in appendix 7.4 or in Servomex Application Note HBAN PM25

4: Sensor Integration

4.1 Sensor Mounting

The sensor can be mounted in one of two ways depending on the variant chosen. If the gas interface is via barbed connectors refer to fig. 3, if the gas interface is via OEM supplied or Servomex fitted piston seal gas ports refer to figs. 4 and 5 respectively.

The method of mounting the sensor shown in fig. 3 is via the factory fitted bracket. The bracket houses 2 off M3 threaded brass inserts located on the underside as shown and are used to secure the sensor onto a flat surface within the host equipment. The inserts are pitched on 21mm centres, see appendix 7.2 for full dimensional information.
The maximum insertion depth for fixing screws is 4mm. Screws inserted beyond this depth will bottom out leaving the sensor poorly secured. Screws should be tightened to a torque value of between 0.35 and 0.45 Nm.

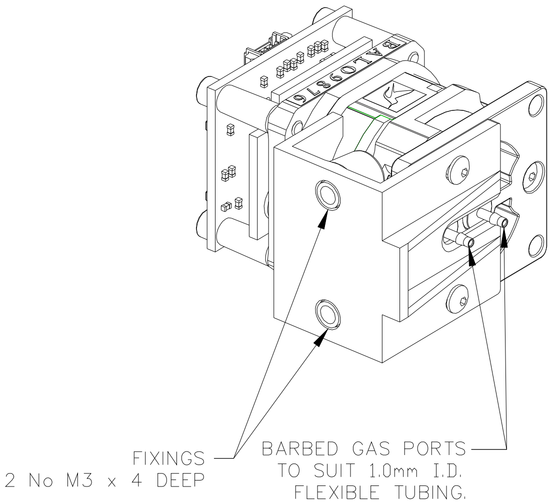


Fig. 3 Sensor pre-fitted with mounting bracket

CAUTION - No. 1
When using fixing bracket to install the Paracube® Sprint, it is important to note that the maximum insertion depth for the fixing screws is 4.0mm.

The sensor mounting method shown in figs. 4 and 5 is via the 4 off 3.2mm diameter clearance holes located on the corners of the flanged moulding. The holes are on 24.7mm and 28.2mm centres.

Fixing is achieved using one of the following two methods;

1. 4 off M3 hexagon socket cap screws (or similar) sited from the sensor side and screwing into M3 tapped in the host equipment.

2. 4 Off M3 screws from the host fixing to 4 off M3 nuts sited on the sensor side of the flange.

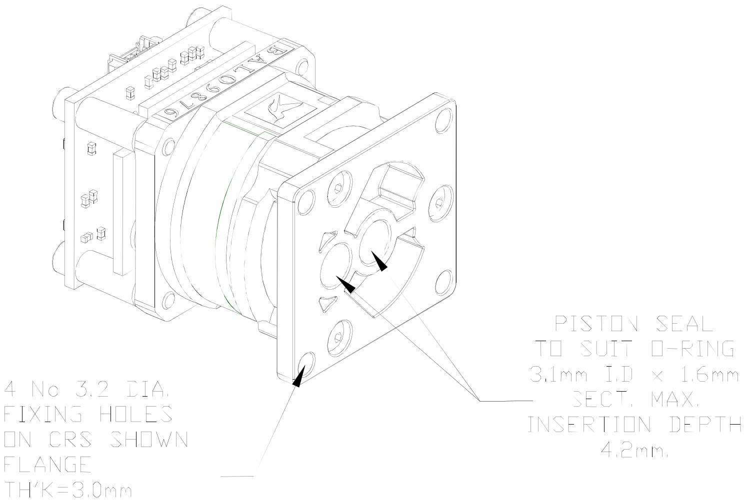


Fig. 4 Flange mounted – gas connection via OEM supplied gas ports

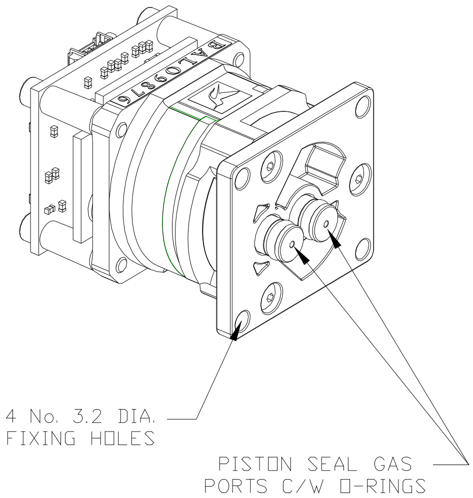


Fig. 5 Flange mounted – gas connection via Servomex supplied gas ports

CAUTION – No. 2
To ensure a gas tight seal for either of the flange type mounting methods, tighten the fixing screws to a torque value of 0.35 to 0.45 Nm.

CAUTION – No. 3
The four screws securing the outer most PCB are factory fitted and should not be removed or used for mounting purposes.

WARNING USE - No. 1
Failure to follow the recommended procedure for fixing of the Sensor may result in leaks exposing personnel to the sample gases.

4.2 Electrical Arrangement

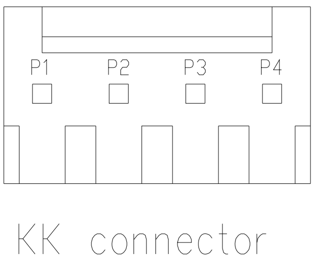
Power Supply (to be provided by the OEM)

The sensor requires an external power supply as specified in Section 3.3.

Electrical Connection
Connection to the sensor is made via a 4 way connector mounted onto the sensor's PCB. There are two connector types offered as standard, a Molex KK type friction lock (fig. 5) or a low profile SMT connector (fig 6). See table 1 for pin out details. Full details of the sensor variants are detailed in section 6.1.

All electrical connections to the sensor must be made using the correct style of "Molex" connector, website www.molex.com

PCB Mounted KK Friction Lock Connector - Molex Part Number 0022272041, fig. 5 2.54mm (.100") Pitch KK® Wire-to-Board Header, Vertical, with Friction Lock. Mating crimp housing required by end-user Molex part number **0022012045** used in conjunction with crimp terminal part number **0008500032.**



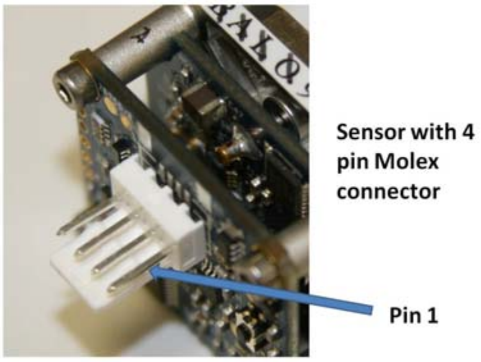
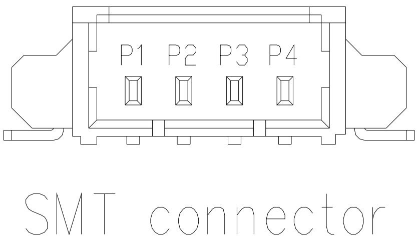


Fig.5

PCB Mounted SMT Connector - Molex Part Number 532610471, fig. 6
1.25mm (.049") Pitch PicoBlade™ Header, Surface Mount, Right Angle.
Mating crimp housing required by end-user Molex part number **0510210400** used in conjunction with crimp terminal part number **0500798000.**



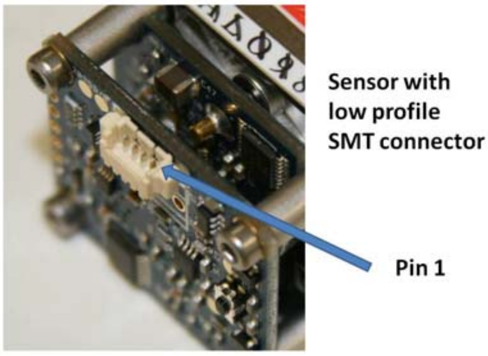


Fig. 6

P1	P2	P3	P4
+5V	Tx	Rx	Earth/Ground

Table 1

Earthing Arrangement
The sensor does not require an external earth connection. Electrostatic potentials are discharged via the power supply 0V connection.

Electrical Separation
The electrical connections to the sensor should be kept to a minimum length. The cable should be of a shielded 4-core construction; connect the electrical screen to the equipment chassis earth star point.

4.3 Communication and Output

UART Compatible communication
The communication is bi-directional UART compatible (non-return to zero) at 19200 baud. There is one dedicated transmit line and one dedicated receive line.

Sensor serial communications summary:
Non return to zero format (NRZ)
0 & 5 Volt signalling voltages
Full duplex
19200-baud transmission rate
8 data bits
1 start bit
1 stop bit
No parity
No handshaking
ASCII text format
Non addressable

Sensor outputs a reading every 10ms +/- 0.5ms.

Output with CRC
Addition of a Cyclic Redundancy Check (CRC) to the sensor output can be enabled / disabled as required by the end-user.

Software within host equipment may use the CRC to detect errors in the communication between the sensor and the host equipment allowing it to avoid using corrupt measurement data.

Refer to table 6 “Digital Interface Commands” section 5.1 for the command to enable or disable the CRC field. All sensors are shipped with the CRC output disabled. The sensor retains the CRC setting over power-cycles.

Refer to table 5 “Sample Output Scenarios” section 5.9 for examples of the sensor output format with and without the CRC field.

Details required to implement a suitable CRC verification algorithm are,

CRC Width	16 Bit
CRC Model	XModem
Polynomial	0x11021 (Expression = $x^{16} + x^{12} + x^{5} + 1$)
Seed Value	0x0
Check Value	0x31c3 (over the string "123456789")

4.4 Location of Sensor

The sensor body should be fixed rigidly to the OEM assembly and away from vibrating components and in particular, care should be taken to avoid mounting the sensor onto a chassis or plate that may act as a lever or spring. If the OEM equipment is subjected to excessive mechanical shocks and vibration during use, it may be necessary to mount the sensor on shock absorbers to dampen the impact on the output of the sensor.

The sensor should be protected from sudden temperature variations, such as from cooling fans, as this can affect both the zero and span calibrations. Fitting the sensor into a temperature controlled environment will eliminate varying environmental conditions and optimise its performance.

4.5 How to Minimise Exposure of Pneumatic System to Contaminants

Keep the components of the pneumatic system, whether in the laboratory or in the production assembly area, away from the "dirty" operations, such as drilling, packaging, filing, cutting, deburring and finishing.

Assemble components in a clean environment and ensure all the components in the sample line tubing have been cleaned for oxygen service and are bagged immediately after cleaning.

4.6 How to Handle the Sensor

Carefully remove the sensor body from the anti-static packaging. Only handle the sensor using **anti-static handling** procedures.

Do not remove the self-adhesive dust cover until the Paracube® Sprint is ready to be fitted in the host instrument.

The sensor should be fitted into the OEM equipment under clean conditions in order to minimise the likelihood of contaminants entering the sensor or the OEM system.

CAUTION – No. 4
The sensor has exposed electronics which are at risk from Electro-Static Discharge (ESD). Only handle the sensor in a static safe environment.

4.7 Orientation of Sensor

Change in Orientation
To achieve optimum performance, the sensor should be operated in the orientation of calibration. Any small offsets resulting from a change in orientation may be removed by performing a single point or full calibration.

4.8 Conditioning of the Sample

The purpose of the sampling system is to convey clean sample gas to the sensor and attention should be paid to the following areas when designing a pneumatic system:

Particulates:
Filtering must remove particles of greater than 3 micron size.

Fluids and water:
Use of a water separator or catch-pot will prevent inflow into the system.

Humidity:
Where appropriate the use of Nafion tube or similar is recommended.

Sample temperature:
To minimise condensation it is recommended that the sensor is operated at +10°C relative to the sample as dew point.

Pump fluctuations:
Depending on the type of sample pump used, it may be beneficial to install a damping volume of between 5mL and 50mL between the sensor and pump.

Back Pressure Effects:
The Paracube® Sprint is a partial pressure device; hence where the sample gas is not exhausted directly to atmosphere care should be taken to avoid errors induced by variations in back pressure.

Reverse Flow:
The Paracube® Sprint is designed such that the sample flow should enter port 1 and exit port 2, see fig. 7. Sudden reversal of the sample flow should be avoided as this may result in permanent damage to the sensor.

Sample line:
Maintaining a consistent internal bore of nominally 1mm ID will optimise the sensor’s response time performance.

4.9 *Pressure Effects:*

The sensor is a partial pressure device and variations in sample gas pressure will cause fluctuations in the observed oxygen output, proportional to the pressure change. Under these circumstances the following methods maybe employed to mitigate this effect.

Method 1 – with Sensor's On-board Pressure Compensation Disabled
Precise control of the sample stream pressure can be adopted by the end user. This applies particularly to pneumatic systems where the sensor is not vented directly to atmosphere, and where restrictions in the sample exhaust will cause the sample back pressure to vary with sample flow, resulting in oxygen reading errors.

This method is only applicable if the sensor forms part of the sealed sample stream, which is independent of ambient pressure swings.

Method 2 - with Sensor's On-board Pressure Compensation Enabled
By employing the sensor's on-board pressure compensation and by selecting the correct variant for the application the oxygen reading is automatically corrected internally with no further action required by the end user. For barometric pressure compensation, select variant 00501701, 00501721 or 00501741. For sample pressure compensation select variant 000501707, 00501727 or 00501747.

The accuracy of error correction achieved by pressure compensation is detailed in section 3.1. Pressure compensation can be enabled / disabled as required by the end-user. Refer to table 6 "Digital Interface Commands" section 5.1 for the command to set the on-board pressure compensation status.

CAUTION – No. 5
Pressure compensation is factory configured to measure internal (sample gas) or external (barometric) pressure. Selecting the right product variant for the application is essential if compensation is to be applied correctly. The compensation is **<u>not interchangeable</u>**.

CAUTION – No. 6
If pressure compensation is toggled between its two operational states a "C" flag will appended to the output indicating a two point calibration is required to ensure a valid oxygen reading.

Method 3 – With Sensor's On-board Pressure Compensation Disabled
In some cases it may be desirable for the end user to perform their own pressure compensation. During sensor calibration, the span gas value and pressure reading should be recorded. These values may then be used to correct the oxygen signal for changes in sample pressure (if sensor is housed in a closed sample system) or barometric pressure (if sensor is open to ambient conditions) according to the following formula (applies if both calibration points are set at the same pressure):

$$\% O_{2comp} = \% O_{2\,ind} \times \left[P_{cal} / P_{ind} \right]$$

Where:

% O_2 comp	: Compensated O_2 value
% O_2 ind	: Current O_2 value
P_{cal}	: Calibration pressure
P_{ind}	: Current pressure

4.10 Use of Sensor with Flammable / Toxic Sample Gases:

The sensor maybe used with flammable / toxic sample gases (for example anaesthetic gases), but due consideration must be given to ensuring the gas interface has high integrity by following the mounting guidelines in section 4.1.

WARNING USE - No. 2
When using the sensor with flammable / toxic sample gases, it is the responsibility of the "Original Equipment Manufacturer" to perform appropriate tests to ensure that it meets their requirements and that the sensor is integrated in accordance with any regional standards or regulations governing the final application.

4.11 Sample Gas Connection:

Correct connection of the sample gas to the inlet and outlet ports is important. The incoming sample gas must be connected to port No. 1, and the exhaust sample gas must be connected to port No. 2. Fig.7 shows the port configuration for the piston seal, but the relative port positions are the same for the barbed connector variant.

CAUTION – No. 7
Incorrect connection of the sample gas may result in damage to the sensor. Ensure that the incoming sample gas is connected to port 1 and the exhaust sample gas is connected to port 2.

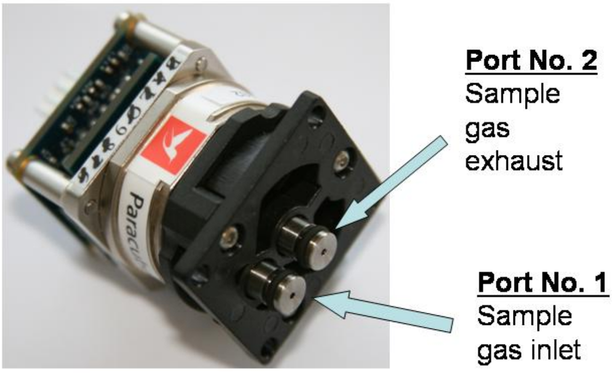


Figure 7

1. **Barbed Gas Ports -** Sample gas connection to sensors fitted with barbed connectors is made via 1mm nominal I/D flexible tubing. The recommended material for the tubing is Tygon®.

2. **OEM designed piston seal**- Reference to fig. 4 shows the sensor's gas interface with two 6.0/6.1mm diameter x 4.40+/- 0.1mm deep counter bores. The counter bores are designed to take a piston type gas port with an "O" ring located on its diameter. The recommended "O" ring is to BS4518, with the British Standard designation 0031-16 (3.1mm I/D x 1.6 mm section). The recommended material for the "O" ring is Viton®.

   Servomex will provide application guidance, where necessary, on the design of the piston seal to suit the OEM requirements.

3. **Servomex fitted piston seal –** Reference to fig. 5 shows the sensor pre-fitted with piston seal gas ports. The mating counter bore on the host equipment must be 6.0/6.1mm diameter x 4.40 +/- 0.1mm. In order to achieve a reliable seal, the surface finish of the counter bore must be 0.8 microns as defined in BS4518.

5: Operation and Calibration

Servomex calibrates the Paracube® Sprint prior to shipment; however you are advised to recalibrate the sensor immediately prior to use to remove any offsets that may have occurred between shipment and installation.

You may employ one of two calibration methods offered by the sensor's software; a full "Two Point Calibration" (see section 5.1) or a "Single Point Offset Correction (SPOC)" (see section 5.3).

The two point calibration is performed when you have access to two gas concentrations with a minimum separation of 20%. This calibration routine will remove any drift and correct the oxygen reading with or without pressure compensation enabled.

The SPOC is performed when you only have access to a single gas concentration (this can be nitrogen), or if a simpler calibration routine is required.

Servomex does not recommend mixing calibration methods on a single device, but if it is unavoidable, always perform a "Restore factory back-up" command when switching between them. See caution No.8.

Caution - No. 8

Zero drift offsets removed by SPOC accumulate and remain stored in the sensor; these will be added to any subsequent two point calibration. To avoid this you must reset the SPOC offset values to zero by performing the "Restore Back-Up" command, by sending ASCII !R↵ prior to your calibration

This is a feature of the SPOC process and to avoid the accumulation of these errors, Servomex strongly recommends that you adopt only one of the two calibration methods.

5.1 Calibration – Initial Conditions

Provide an external power supply as described in section 3.3
Configure the sensor communication as described in section 4.3.
Provide calibration gases certified to 0.1% oxygen accuracy with a constant gas flow

5.2 Two Point Full Calibration

A full calibration of the sensor can be completed by using two gases which have a minimum oxygen concentration difference of 20%. Follow the example given in “Flow Chart 1” below for the procedure of a typical calibration. The command set is described in table 6. While the sensor performs the two point calibration, each line of output from the sensor will contain a single ‘S’.

An appropriate delay should be employed between gas exchanges to ensure that the gas has stabilised.

Either a low gas calibration or a high gas calibration may be performed first as part of the two point calibration process.

Start	
Apply cal 1 gas to the Pm00501 (33% O_2 in this example)	Cal 1 = 0% O_2 Cal 2 = 100% O_2
Allow the Pm00501 output signal to stabilise ≈ 30 sec’s	Cal 1 = 0% O_2 Cal 2 = 100% O_2
Send ASCII code: Cal 1gas = 33.0% O_2: ASCII !L33↵	Cal 1 = 33% O_2 Cal 2 = 100% O_2
Apply cal 2 gas to the Pm00501 (55% O_2 in this example)	Cal 1 = 33% O_2 Cal 2 = 100% O_2
Allow the Pm00501 output signal to stabilise ≈ 30 sec’s	Cal 1 = 33% O_2 Cal 2 = 100% O_2
Send ASCII code: Cal 2 gas = 55.0% O_2: ASCII !H55↵	Cal 1 = 33% O_2 Cal 2 = 55% O_2
Stop	

Flow chart 1.

5.3 Single Point Offset Correction (SPOC)

Expose the sensor to a known gas concentration in the range 0.0% O_2 to 100.0% O_2 for a minimum of 30s. Send the command !Snnn.n↵ to perform the SPOC, where nnn.n is the known gas concentration. While the sensor performs the SPOC, each line of output from the sensor will contain a single 'S'.

During a SPOC the sensor's internal pressure device is used to distinguish zero drift from pressure effects. The pressure device **must** be exposed to the sample gas, regardless of whether your sensor variant has pressure compensation enabled. If the pressure device cannot measure the sample gas pressure, errors will be introduced into subsequent readings. Figure 8 illustrates the effects of zero drift and ambient pressure variation.

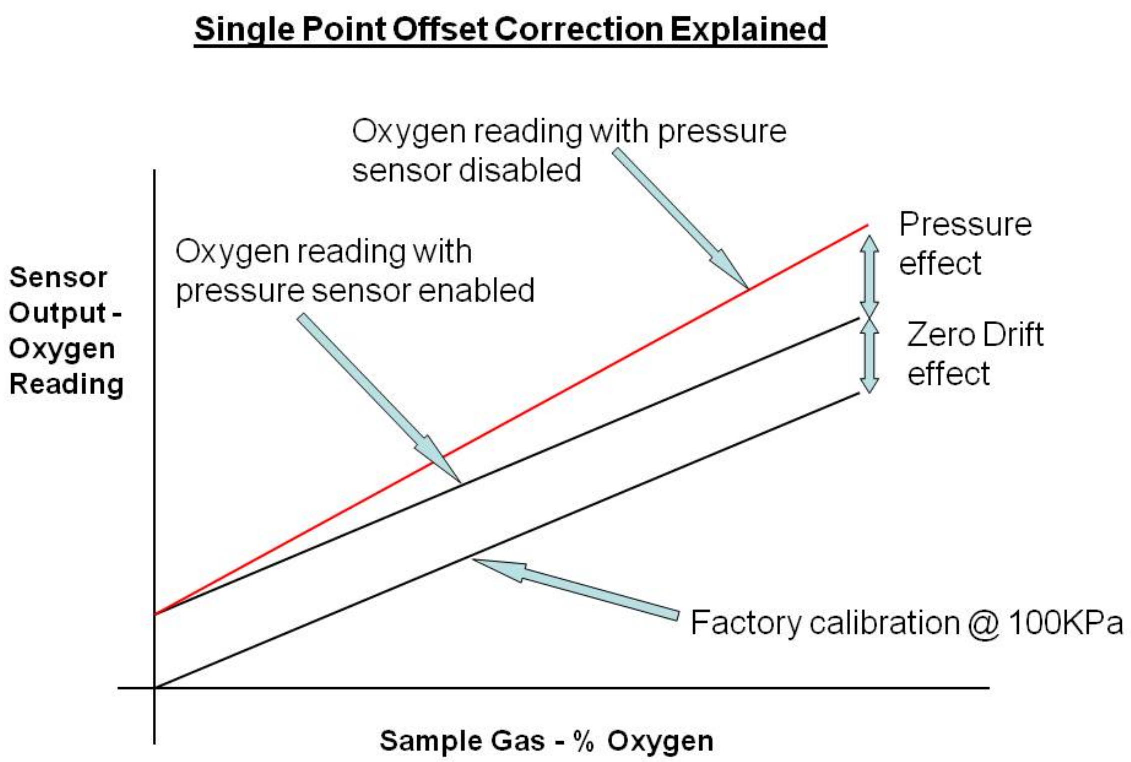


Figure 8

If you are using a sensor variant that has pressure compensation disabled, oxygen concentration values reported by the sensor are compensated relative to the factory calibration pressure of 100kPa.
To correct the oxygen reading following a SPOC, you will need to measure the sample gas pressure, and compensate using the expression for pressure compensation detailed in method 3 of section 4.9. You should use a value of 100 for P_{CAL} reflecting the factory calibration pressure of 100kPa and your measured pressure P_{IND} must also be in the same units. See caution 9.

Caution - No. 9

If your sensor has pressure compensation disabled, oxygen readings following a SPOC may not reflect the known gas concentration. This will be due to changes in sample gas pressure. The SPOC procedure **only removes the drift component** from the oxygen reading.

5.4 Zero Drift Offset Correction in the Host Equipment

To optimise measurement accuracy between routine two point calibrations, a single point adjustment may be made. This type of adjustment must be made within the host unit software.
Apply a known concentration of oxygen, eg air (20.9% O_2) to the sensor, and store in the host system memory the difference between the oxygen reading and the known oxygen concentration. Subsequent oxygen readings may then be corrected by removing this stored offset value.

5.5 Restore Factory Calibration

The sensor can be returned to its original factory calibration by sending the restore factory calibration backup command "Restore Back-Up" sending ASCII !R↵.

5.6 LED sensor status

The dual colour LED located on upper circuit board provides a visible indication of the calibration status or the sensor's health.

1. Under normal operating conditions and with valid calibration data the LED will emit a constant green light.

2. If a full two point calibration or a SPOC are unsuccessful, the LED will emit an amber light, flashing at 2Hz and 20% duty cycle. This LED status will remain until a successful two point calibration or SPOC is achieved. During this period the sensor will use the previous valid calibration/SPOC data to provide the sensor's oxygen reading.
3. If after applying power to the sensor, it cannot initiate the micro-processor the LED will emit a static red light indicating sensor failure.

5.7 Format of the Sensor Output

Table 3 below describes the format of the sensor's output

ASCII Character Position	Normal use for a Character in this Position	Alternative Usage (dependent on measurement and sensor status)
1	Hundreds Digit	Replaced by space instead of leading zero for readings <100 Could show minus sign for negative readings Will show X if a fatal failure is detected Will show S during transducer calibration
2	Tens Digit	Replaced by space instead of leading zero for readings <10 Could show minus sign for negative readings Carriage return if X or S in ASCII Character Position 1
3	Units Digit	Always zero when reading -1< reading <1 Unused if X or S in ASCII Character Position 1
4	Decimal Point	Unused if X or S in ASCII Character Position 1
5	Tenths Digit	Unused if X or S in ASCII Character Position 1
6	Space	Will show B if a bad command has been received Unused if X or S in ASCII Character Position 1
7	Space	Will show C if the minimum calibration point separation has not been maintained Unused if X or S in ASCII Character Position 1
8	Space	Will show E if the transducer is operating outside specification Unused if X or S in ASCII Character Position 1
9	Carriage Return	Unused if X or S in ASCII Character Position 1
10	Unused	Will show 2nd hexadecimal digit of CRC if that option is enabled. Unused if CRC option is disabled.
11	Unused	Will show 3rd hexadecimal digit of CRC if that option is enabled. Unused if CRC option is disabled.
12	Unused	Will show 4th hexadecimal digit of CRC if that option is enabled. Unused if CRC option is disabled.
13	Unused	Will show Carriage Return if CRC option is enabled.

Table 3

5.8 Status Flags

Table 4 below details the error flags and the possible causes.

Status Flag	Possible Cause	Recommended Action
X	Electrical or sensing element malfunction	Return sensor to Servomex
	Sensor exposed to extreme temperatures	Return sensor to Servomex
E	Sensor is being operated outside of specification or signal levels are unstable Possible liquid or particulate contamination of the diffusion port	Check environmental operating conditions including physical mount. Ensure gas port is clean and dry. Perform calibration If 'E' flag persists return sensor to Servomex
B	Incorrect character string sent to sensor or character string sent during calibration or SPOC	Send carriage return and interrogate for serial number
	Invalid calibration request	Send carriage return and perform calibration
C	Difference between two calibrate points is less than 20% O_2	Check calibration gases and repeat calibration procedure
	Pressure compensation has been enabled or disabled but low and high calibration has not been performed.	Perform a full two point calibration
S	Calibration in progress	Wait for calibration to complete. A calibration takes no more than 4 seconds

Table 4

5.9 *Sample Output Scenarios*

The following table shows a number of examples of the output to indicate the positioning of the measurement and status flags under various conditions.

Note: In the table below the symbol ↵ signifies a carriage return character.

CP-1…..9 = character positions 1 through 9 of the sensor output.

Scenario	CP-1	CP-2	CP-3	CP-4	CP-5	CP-6	CP-7	CP-8	CP-9	CP-10	CP-11	CP-12	CP-13
0%	Space	Space	0	.	0	Space	Space	Space	↵				
20.9%	Space	2	0	.	9	Space	Space	Space	↵				
100.0%	1	0	0	.	0	Space	Space	Space	↵				
-15.2%	-	1	5	.	2	Space	Space	Space	↵				
-1.5%	Space	-	1	.	5	Space	Space	Space	↵				
Bad Command	Space	2	0	.	9	B	Space	Space	↵				
Bad Calibration	Space	1	5	.	0	Space	C	Space	↵				
Operating Out of Spec	1	2	2	.	1	Space	Space	E	↵				
Calibrating	S	↵											
Fatal Failure	X	↵											
20.9% with CRC option	Space	2	0	.	9	Space	Space	Space	D	1	4	A	↵
Bad Command with CRC option	Space	2	0	.	9	B	Space	Space	2	4	4	1	↵

Calibrating with CRC option	S	Space	Space	Space	Space	Space	Space	Space	C	3	5	7	↵
Fatal Failure with CRC option	X	Space	Space	Space	Space	Space	Space	Space	1	5	F	8	↵

Table 5

B, C and E flags may coexist.
S, X flags are prioritised such that X has a higher priority than S.

5.10 Digital Interface Commands

The digital interface provides commands that allow information to be read and for certain actions to be invoked.
Where commands read data the response will be given within 200ms.
Note: In the table below the symbol ↵ signifies entry of a carriage return character.

Action	**Command**	**Valid Parameters**	**Effect**
Read Product Identity Code	! ↵	None	The sensor will respond by sending an exclamation mark “!” followed by a unique “sensor identity code”, comprising the product code, the product variant number and the serial number of the form; XXXXXYYYZZZZZZ Where XXXXX is the product code, YYY is the product variant number and ZZZZZZ is the numeric serial number, incrementing from 000001
Read Firmware Revision	!F↵	None	Displays the firmware revision number. This should be quoted in any technical queries to Servomex
Switch between Digital and Analogue output modes	!I <State>↵	Where <State> is 0 = Digital Mode, 1 = Analogue Mode	Toggles the sensor between Digital and Analogue output modes.

Read if internal pressure compensation is enabled or disabled	!P↵	None	Displays 0 if internal pressure compensation is disabled or 1 if it is enabled
Enable or disable internal pressure compensation	!Pn↵	Where n is, 0 to disable pressure compensation 1 to enable pressure compensation	Enables or disabled internal pressure compensation being applied to the reported oxygen measurement
Enable or disable CRC field in digital output	!Cn↵	Where n is, 0 to disable CRC field. 1 to enable CRC field.	Enables or disables output of a CRC field in the digital output. CRC uses the 16 bit XMODEM CRC model with, Polynomial=$x^{16} + x^{12} + x^5 + 1$ *(0x11021)* and Seed value=0x0
Low Calibrate	!Ln.n↵	Where n is a number in the range 0 to 100 indicating the oxygen content of the calibration gas A decimal point may be used where necessary	Invoke a low calibration. This variant of the calibration command can be used to specify which of the two sets of calibration data is updated. This command updates the low cal point
High Calibrate	!Hn.n↵	Where n is a number in the range 0 to 100 indicating the oxygen content of the calibration gas A decimal point may be used where necessary	Invoke a high calibration. This variant of the calibration command can be used to specify which of the two sets of calibration data is updated. This command always updates the high cal point
Single Point Offset Correction (SPOC)	!Sn.n↵	Where n is a number in the range 0 to 100 indicating the oxygen content of the calibration gas A decimal point may be used where necessary	A single point offset correction adjusts for drift of the sensor with time and can be used where a two point calibration is not possible under normal working conditions
Restore backed up calibration	!R↵	None	In the unlikely event that during a calibration or a SPOC the procedure goes wrong the sensor can be recovered to its original factory calibration by sending the restore factory calibration backup command

Table 6

6: Variants, spares, packaging and warranty

6.1 Sensor Variants Options – As Shipped from Servomex

Variant part numbers: Lists Digital only for Analogue see manual Pt. No. 00501009A

Product Variant Number	Digital output	Analogue Output 0.5mV/% O_2	Analogue Output 10.0mV/% O_2	SMT Conn.	KK friction lock Conn.	Ext. Press. Comp.	Int. Press. Comp.
Face Seal variant - without gas ports							
00501701	**Y**			**Y**		**Y**	
00501707	**Y**			**Y**			**Y**
00501715	**Y**			**Y**			
00501716	**Y**				**Y**		
Face Seal - with piston type seals							
00501721	**Y**			**Y**		**Y**	
00501727	**Y**			**Y**			**Y**
00501735	**Y**			**Y**			
00501736	**Y**				**Y**		
Bracket mount - with gas ports							
00501741	**Y**			**Y**		**Y**	
00501747	**Y**			**Y**			**Y**
00501755	**Y**			**Y**			
00501756	**Y**				**Y**		

Table 7

6.2 Spares

The sensor has no serviceable parts.

Instruction Manual Digital variants, part number **00501001A**
Instruction Manual Analogue variants, part number **00501009A**

6.3 Special Packaging

The sensor is manufactured in Class 10,000 clean room conditions. The sensor is fitted into anti-static packaging for transport, and it is recommended that the sensor is stored in this packaging until required for production.

6.4 Product Failure during Warranty

Servomex will repair or replace free of charge any unit that has failed whilst under warranty, providing the root cause of failure is due to faulty materials, design or manufacture. Failures due to misuse will not be considered for replacement under warranty. Examples of failures resulting from misuse include, but are not limited to, failures due to excessive flow or pressure and failures due to contamination or condensate in the cell. Under these conditions Servomex reserves the right to charge for replacement.

6.5 Product Failure Out of Warranty

Servomex will always examine sensor returns on request to determine the root cause for a reported product failure, but accept no obligation to replace the sensor.

6.6 Maintenance and Servicing

There is no requirement for regular maintenance or servicing of the Paracube® Sprint.

The Paracube® Sprint offers the Servomex non-depleting paramagnetic technology with unlimited shelf life. Providing there is adequate control of flow and pressure, with no cell contamination by fluids or particulates, there are no components that will require regular maintenance.

6.7 Decontamination

It is important that only general purpose alcohol based cleaning agents be applied to the external surfaces of the Paracube® Sprint.

NOTE:

Contaminated cells should be disposed of in accordance with the local Environmental and Health & Safety regulations.
Servomex reserves the right to refuse to examine product returned without a completed Decontamination Clearance Certificate.
Appropriate anti-static handling procedures should be applied and returns must be packed in the original material to prevent damage during transport.

WARNING USE – No. 3
All parts of the sensor including gas ports shall be decontaminated and returned with a “Decontamination Clearance Certificate”, before Servomex will examine the product.

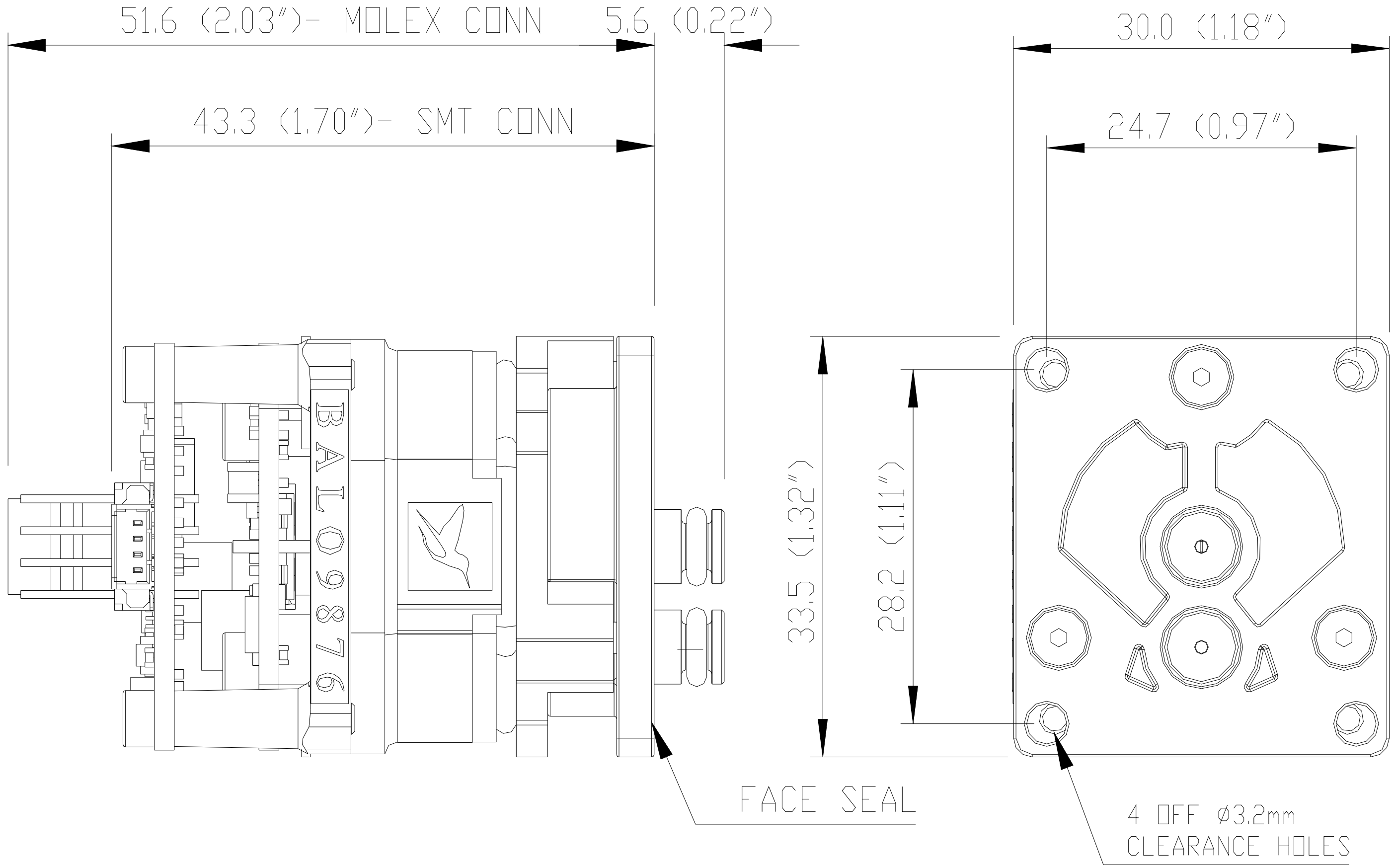
6.8 RoHS and WEEE Directives

RoHS - The sensor has been designed to comply with the RoHS directive and contains no hazardous components listed by this directive.
The Restriction of Certain Hazardous Substances (RoHS) Directive restricts the use of certain toxic substances, such as lead, in printed circuit boards.

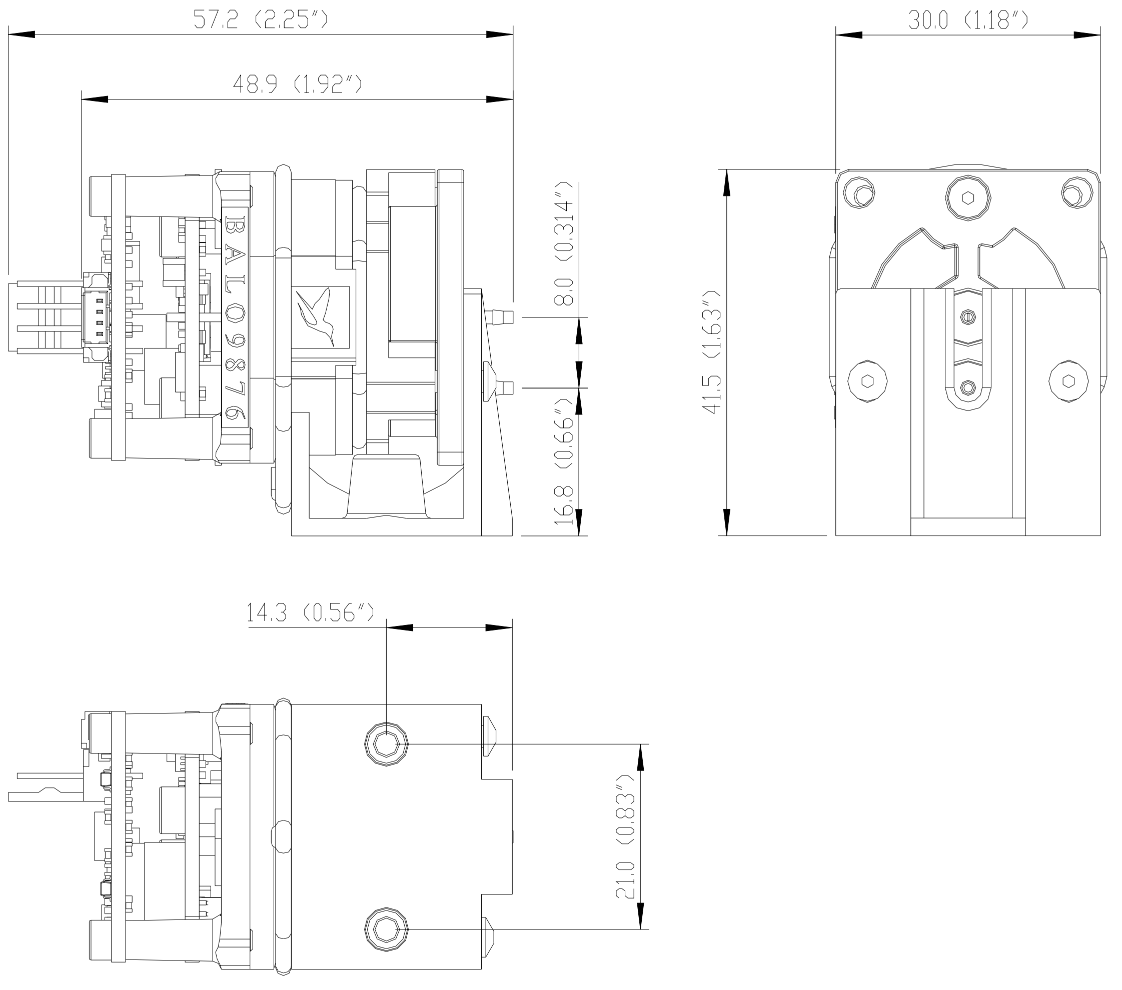
WEEE - The European Waste from Electrical and Electronic Equipment (WEEE) Directive aims to reduce the amount of WEEE going to landfill, by requiring all manufacturers and producers to take responsibility for what happens to the products they sell at the end of their lives. Servomex will comply with this directive and responsibly dispose of the components that are present in the build if sensors are returned to Servomex for disposal.
Servomex will advise OEMs on how to dispose of components if requested.

7: Appendices

Appendix 7.1 Outline Dimensions, Face seal with/without gas ports as required



Appendix 7.2 Outline Dimensions, Bracket mount with barbed gas ports



Appendix 7.3 Mechanical Vibration and Shock Resistance

The sensor will meet the requirements of the following clauses of the International Standard IEC 68-2 Basic Environmental Testing Procedures.

BS EN 60068-2-27:1993 (IEC 68-2-27) Shock

Peak acceleration:	100g (980 ms^{-2})
Duration:	6 ms
Pulse shape:	Half sine

BS EN 60068-2-6:1996 (IEC 68-2-6) Sinusoidal Vibration

Frequency range:	10Hz to 500 Hz
Acceleration amplitude:	1g (9.8ms^{-2})
Type and duration of endurance:	10 sweep cycles in each axis

IEC 68-2-34 Random Vibration, Wide Band

Frequency range:	20Hz to 500Hz
Acceleration spectral density:	$0.02g^2Hz^{-1}$
Duration:	9 min

Appendix 7.4 Sample Gas Cross Sensitivity Guide

Gas	Formula	Gas	Formula
Acetylene	HCCH	Freon 114	C_2Cl_2F4
Alkyl alcohol	CH_2CHCH_2OH	Halothane	$C_2HBrClF3$
Argon	Ar	Helium	He
Benzene	C6H6	n-Heptane	C7H16
1,2 Butadiene	C4H6	n-Hexane	C6H14
1,3 Butadiene	C4H6	Hydrogen	H_2
n-Butane	C4H10	Isoflurane (Forane)	$C3H_2F5ClO$
iso-Butane	$(CH3)\ _2CHCH_2$	Krypton	Kr
iso-Butylene	$(CH3)\ _2CH=CH_2$	Methane	CH4
1 Butyne	$CH3C3H_2$	Methyl cyclopentane	$C6H1_2$
Carbon dioxide	CO_2	Monochlorobenzene	C6H5Cl
Carbon disulphide	CS_2	Neon	Ne
Carbon monoxide	CO	Nitrogen	N_2
Carbon tetrachloride	CCl4	Nitrous oxide	N_2O
Carbon tetraflouride	CF4	n-Nonane	$C9H_20$
Chloroform	CHCl3	n-Octane	C8H18
Cyclohexane	$C6H1_2$	Oxygen	O_2
Cyclopentane	C5H10	Ozone	O3
Cyclopropane	C3H6	iso-Pentane	$C5H1_2$

Dichloroethylene	$(CHCl)_2$	n-Pentane	$C5H1_2$
Freon 11	CCl3F	Phenol	C6H5OH
Freon 12	CCl_2F_2	Propane	C3H8
Freon 113	$CHCl_2CH_2Cl$	iso-Propanol	$(CH3)_2CHOH$
Enflurane(Ethrane)	$C3H_2F5ClO$	Propene	$CH3CH=CH_2$
Ethane	C_2H6	Propylene	C3H6
Ethanol	C_2H5OH	Styrene	$C6H5CH=CH_2$
Ethyl acetate	$CH3COOC_2H5$	Tetrachoroethylene	$Cl_2C=CCl_2$
Ethyl chloride	C_2H5Cl	Vinyl chloride	$CH_2=CHCl$
Ethylene	C_2H4	Xenon	Xe
Ethylene glycol	$(CH_2OH)_2$		

HUMMINGBIRD
SENSING TECHNOLOGY

Revision History Sheet

Manual: 00501001A

Ref No.	Page(s) Affected	Summary of Change	Changed by	Approve by and Date
00501001/0	All	First issue of manual	CRE	MC Feb 2011
00501/001/1	Page 12	Altitude operating range was -250m, now -500m. (ECN 11-089)	CRE	MC May 2011
00501/001/2	Page 19	Tolerance added to update rate	CRE	13-01-12

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