



Hummingbird
SENSING TECHNOLOGY



Paracube™ Sprint

NEKTA®
quick connect

Digital Paramagnetic Oxygen Sensor Module

Instruction Manual

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Product Part Numbers: 00502/XXX series



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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.

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

NOTES: Alerts the user to pertinent facts and conditions.

WARNING (USE) – No.1

AS THE FINAL CONDITIONS OF USE ARE OUTSIDE HUMMINGBIRD'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 – No.1

For safety reasons any sensor returned to Hummingbird must be accompanied by the Decontamination Clearance Certificate contained in this manual. Unless the cell is accompanied by this certificate, Hummingbird 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 – No.2

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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

Hummingbird 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 Hummingbird 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 Hummingbird 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 Hummingbird 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 Hummingbird employees and its representatives to handle, unpack, examine and work upon the equipment described below.

Equipment _____

Reason for return

Serial no _____

Signature _____

Print name _____

Company _____

Position _____

Company seal or stamp: -

Date _____

Form: 5000/2 issue2



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1 Introduction

The Paracube™ Sprint represents the latest generation of Hummingbird'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 Hummingbird'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.

Hummingbird'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. 3

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.



2 Hummingbird 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.

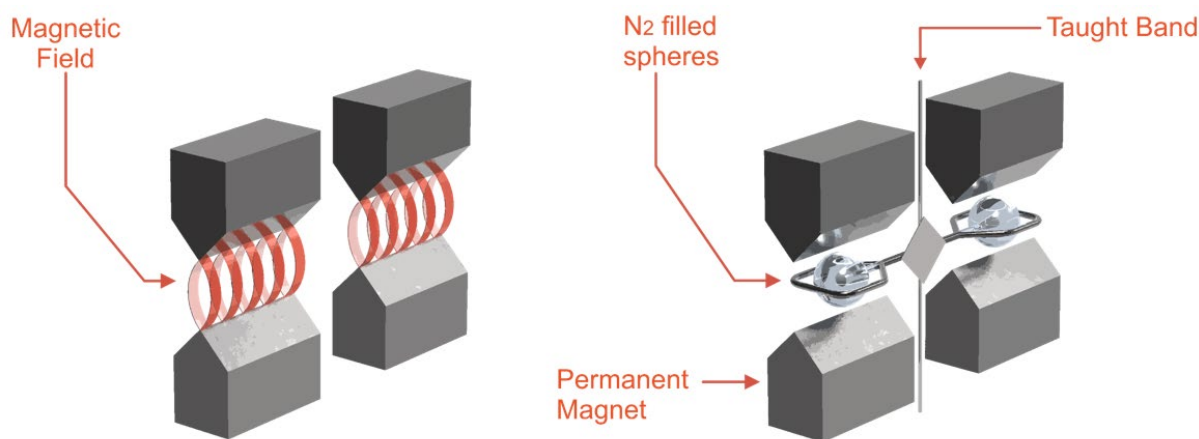


Figure 1

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.

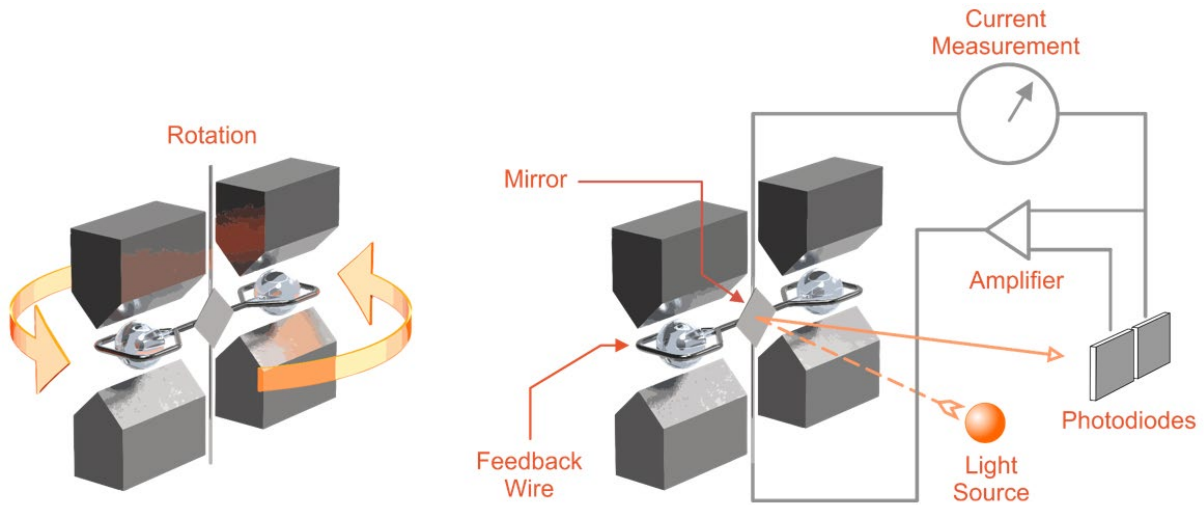


Figure 2

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 N₂ and 100% O₂ 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 61207-1:2010.

Operating Range

0 to 100% O₂ with over range capability -15% O₂ to +200% O₂

Intrinsic Error[†]

<±0.2% O₂

Linearity[†]

<±0.2% O₂

Repeatability[†]

<±0.2% O₂

Signal Noise (peak to peak)[†]

<0.2% O₂

Zero Stability (permanent drift from calibration value)[†]

<±0.4% O₂ for first 24 hours

<±0.2% O₂ for the subsequent week (additional)

<±0.2% O₂ per month thereafter (additional)

Temperature Coefficient

Zero: <±0.5% O₂ / 10°C

Span: <±0.5% of O₂ reading / 10°C



Response Time

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

Gas Exchange	Sample Flow Rate	Response Time
16% - 21% O ₂	50ml min ⁻¹	1,450 ms
	120ml min ⁻¹	585 ms
	190ml min ⁻¹	300 ms
	250ml min ⁻¹	250 ms
21% - 100% O ₂	50ml min ⁻¹	1750 ms
	120ml min ⁻¹	800 ms
	190ml min ⁻¹	520 ms
	250ml min ⁻¹	400 ms

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

Gas Exchange	Sample Flow Rate	Response Time
21% - 16% O ₂	50ml min ⁻¹	1,500 ms
	120ml min ⁻¹	550 ms
	190ml min ⁻¹	295 ms
	250ml min ⁻¹	235 ms
100% - 21% O ₂	50ml min ⁻¹	1,875 ms
	120ml min ⁻¹	750 ms
	190ml min ⁻¹	400 ms
	250ml min ⁻¹	290 ms

NOTE – No.4

The published values are for guidance only and actual values achieved will be dependent on the customer application.

**Flow Error**

<±0.3% for 10ml/min change in flow rate within the operating flow range (50 to 250ml/min)
Based on gases with molecular weights between 28 and 32g/mol. Contact Hummingbird' Applications Department for gases with higher molecular weights.

Pressure Range

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

Tilt

<±0.5% O₂ equivalent for 15° change in orientation from the calibration point.

Time to Valid Reading

Valid output from power up for a fully stabilised sensor <4 seconds.
For a non-stabilised sensor, the time to a valid reading will depend on the environmental conditions of the application.

Pressure Compensation

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

3.2 Mechanical Specification

Dimensions (W X D X H)

The sensor can be supplied with a choice of two electrical connectors which modifies its height 'H' as follows: -

Low profile SMT connector

33.5mm x 30mm x 37.6mm (imperial dims. 1.32" x 1.18" x 1.48")

Type KK friction lock connector

33.5mm x 30mm x 46.1mm (imperial dims. 1.32" x 1.18" x 1.81")

For full outline dimensions refer to Appendix 7.1 and 7.2

Weight

70 grams (2.47 ounces).

Pneumatic Leakage

<3x10⁻⁴ mbar.L.sec⁻¹ (<3x10⁻⁴ SCCS).

Operational flow rate

50 to 250ml/min, Max purge at 300ml/min.

**Materials in Contact with Sample Gas**

Stainless steel grades 316, 316L, 302S25 and 304(1.4301)
Borosilicate glass & alkali borosilicate glass
Polyphenylene sulphide (PPS) with carbon / glass filler
Platinum and platinum iridium alloy
Nickel
Fluorocarbon elastomer -FPM (Viton)
Krytox GPL205 grease

This list represents the bulk materials that may be contact with the sample gas. However, the sensor production process requires the use of additional materials which may include cutting media, solvents and cleaning agents and whilst Hummingbird production processes endeavour to remove any residual materials, trace levels may remain in the final product.

3.3 External Power Supply Specification

+5V dc $\pm 5\%$, 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 = 110mA typical 150mA max
A change of $\pm 0.25V$ in supply Voltage results in a change of less than $\pm 0.1\%$ 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 O₂ 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% O₂ 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°C, for 100% concentration is shown below:

Interfering Gas	Interference Effect (100% Interferent % O ₂)
N ₂ O	-0.20
CO ₂	-0.26
H ₂ O	-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 Hummingbird Application Note HBST 0017 - Torque Balance Paramagnetic Measurements Sample Gas Cross Sensitivity. The application note can be downloaded from Hummingbird.com.



3.5 Biocompatibility

Hummingbird engaged MedPass International the medical device CRO (Clinical Research Organisation) to carry out a Biological Safety Evaluation of the Hummingbird Paracube™ to demonstrate its biological safety and biocompatibility. A full copy of this report is available on request.

The Paracube™ has been assessed to and complies with the requirements of the following biocompatibility standards;

ISO 10993-5, Cytotoxicity.

ISO 10993-10, Sensitisation.

ISO 18562-2-2017 - Biocompatibility evaluation of breathing gas pathways in healthcare applications – Part 2: Tests for emissions of particulate matter.

ISO 18562-3-2017 - Biocompatibility evaluation of breathing gas pathways in healthcare applications – Part 3: Tests for emissions of Volatile Organic Compounds.



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 Hummingbird 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.

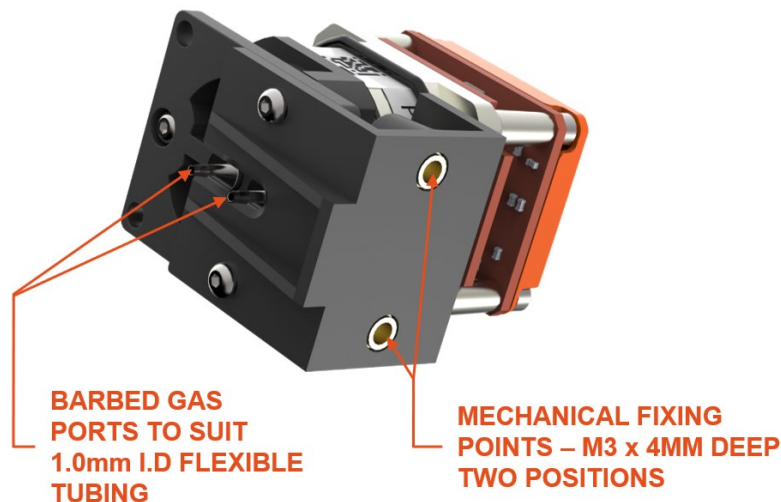


Figure 3 Sensor pre-fitted with mounting bracket

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.

**CLEARANCE
MOUNTING
HOLES - 3.2mm
DIA FOUR
POSITIONS. ON
CRS FLANGE
3.0mm THICK**



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

**CLEARANCE
MOUNTING
HOLES - 3.2mm
DIA FOUR
POSITIONS. ON
CRS FLANGE
3.0mm THICK**



Fig. 5 Flange mounted – gas connection via Hummingbird 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. 2

FAILURE TO FOLLOW THE RECOMMENDED PROCEDURE FOR FIXING OF THE SENSOR MAY
RESULT IN LEAKS EXPOSING PERSONNEL TO THE SAMPLE GASES.

4.2 Sensor Identification

The sensor is fitted with an identification label that states the product type, product catalogue number, variant type and unique identification serial number. This data is presented in three formats – Human readable (alpha numeric), QR Code and Data Matrix ECC 200

4.3 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**.

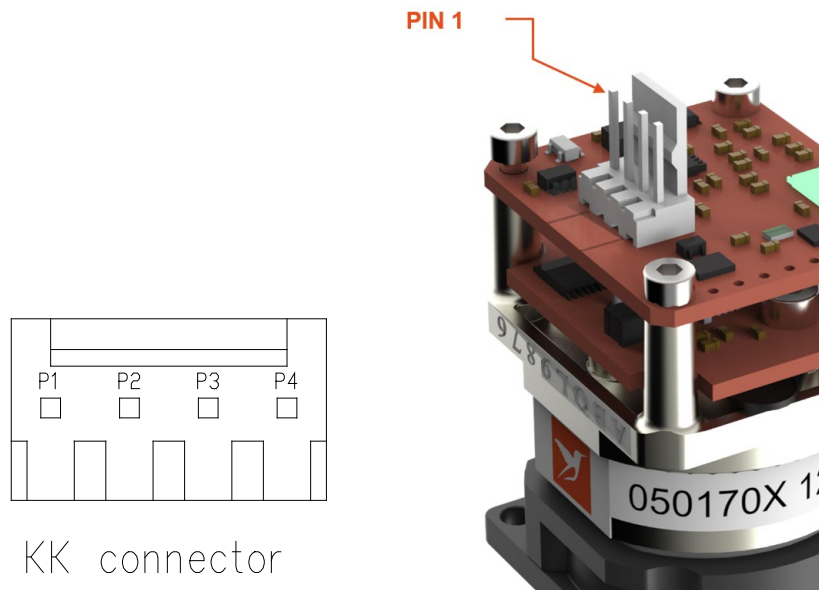


Figure 5 Sensor with 4 pin KK Friction Lock Connector

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**.

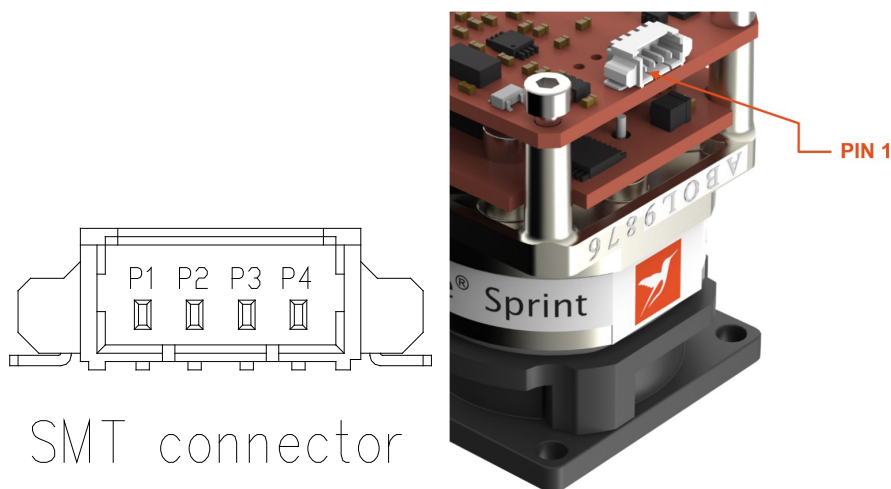


Figure 6 Sensor with Low Profile SMT Connector

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

Table 1

**Connector Details**

Pins 1 and 4 (P1 and P4) shown in Table 1 above are used to supply power to the sensor, pins 2 and 3 (P2 and P3) provide the sensor's UART serial communications.

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 <15cm. The cable should be of a shielded 4-core construction; connect the electrical screen to the equipment chassis earth star point.



4.4 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 every 10ms +/- 0.5ms a reading

Output with CRC (Cyclic Redundancy Check)

Addition of a 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 section 5.10 “Digital Interface Commands” 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")

Alternative CRC methods are available on request.



4.5 Location of Sensor

The sensor body should be fixed rigidly to the OEM assembly and away from vibrating components and 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.

CAUTION - No. 4

Operation of the sensor in environments subject to mechanical shock and vibration will result in erroneous oxygen readings being reported.

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.

4.6 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.

4.7 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 ParacubeTM 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. 5

The sensor has exposed electronics which are at risk from Electro-Static Discharge (ESD). Only handle the sensor in a static safe environment.



4.8 Orientation of Sensor

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 offset correction or a full calibration.

4.9 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

Condensation within the sensor may be avoided by ensuring that the sensor temperature is at least 10°C above the sample gas 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 ParacubeTM 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 ParacubeTM 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.

4.10 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 00502701, 00502721 or 00502741. For sample pressure compensation select variant 000502707, 00502727 or 00502747.

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 section 5.10 "Digital Interface Commands" for the command to set the on-board pressure compensation status.

CAUTION – No. 6

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 not interchangeable.

CAUTION – No. 7

If pressure compensation is toggled between its two operational states a "C" flag will be 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):

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

Where:

% O_{2 comp} : Compensated O₂ value

% O_{2 ind} : Current O₂ value

P_{cal} : Calibration pressure

P_{ind} : Current pressure



4.11 Use of Sensor with Flammable / Toxic Sample Gases

The sensor may be 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. 3

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.

4.12 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. 8

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.

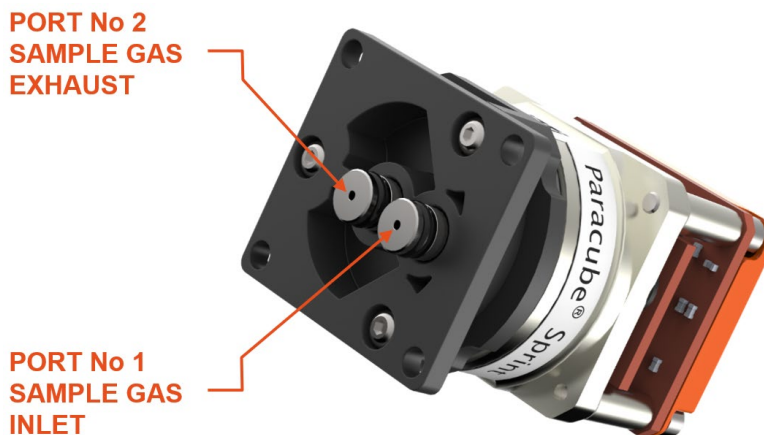


Figure 7 Sample Gas Ports



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®.

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

3. **Hummingbird 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

Hummingbird calibrates the ParacubeTM Sprint prior to shipment; however, the user **MUST** 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.

Hummingbird 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. 9

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, Hummingbird 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.

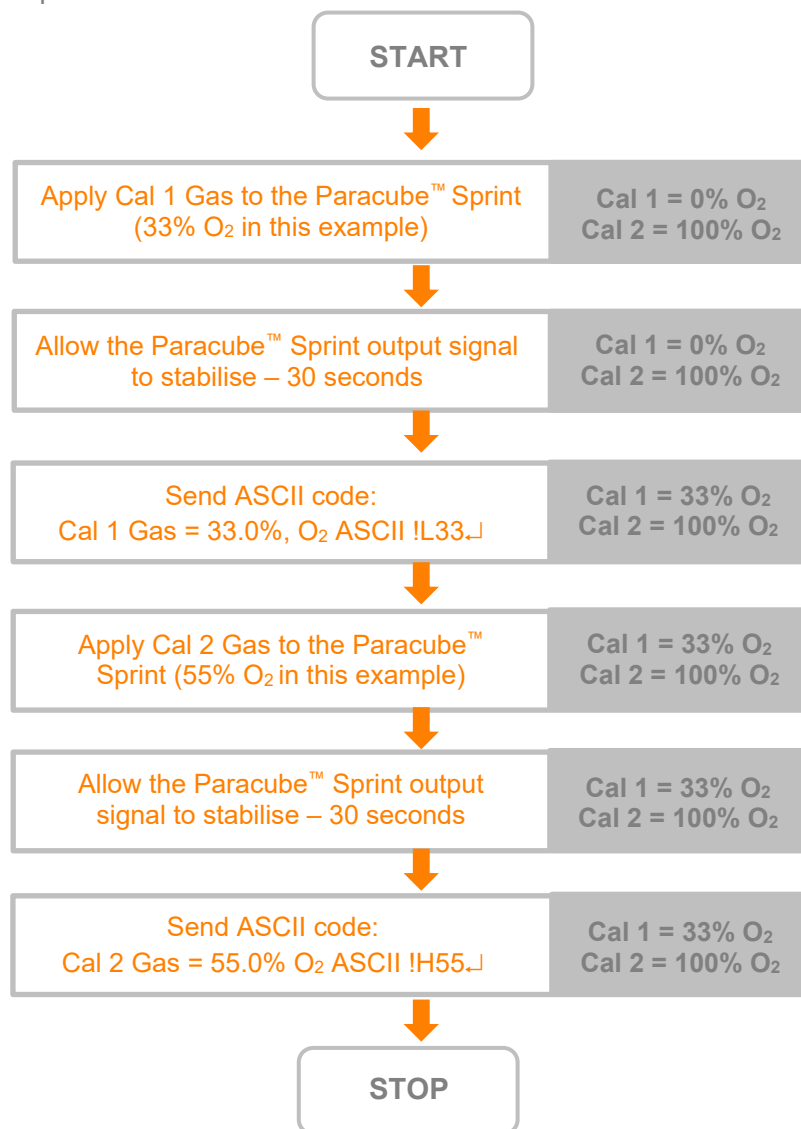


5.2 Two Point Full Calibration

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.





5.3 Single Point Offset Correction (SPOC)

During a SPOC the sensor's on-board pressure device is used to distinguish zero drift from pressure effects, irrespective of whether the on-board pressure device provides active compensation or not. The effect of pressure on the live oxygen reading is calculated by comparing the monitored pressure with the factory calibration pressure and is removed before the offset correction is applied. This ensures that only the drift component is being corrected.

For the effect of pressure to be removed correctly during a SPOC, the on-board pressure device **must** be exposed to the same pressure as the calibration gas. All sensors, other than those that offer "Sample Pressure Compensation", see Table 7, will correct based on barometric pressure. If the pressure of the calibration gas and barometric pressure are not the same, further correction will be required by the host software.

Figure 8 illustrates the effects of zero drift and pressure variation.

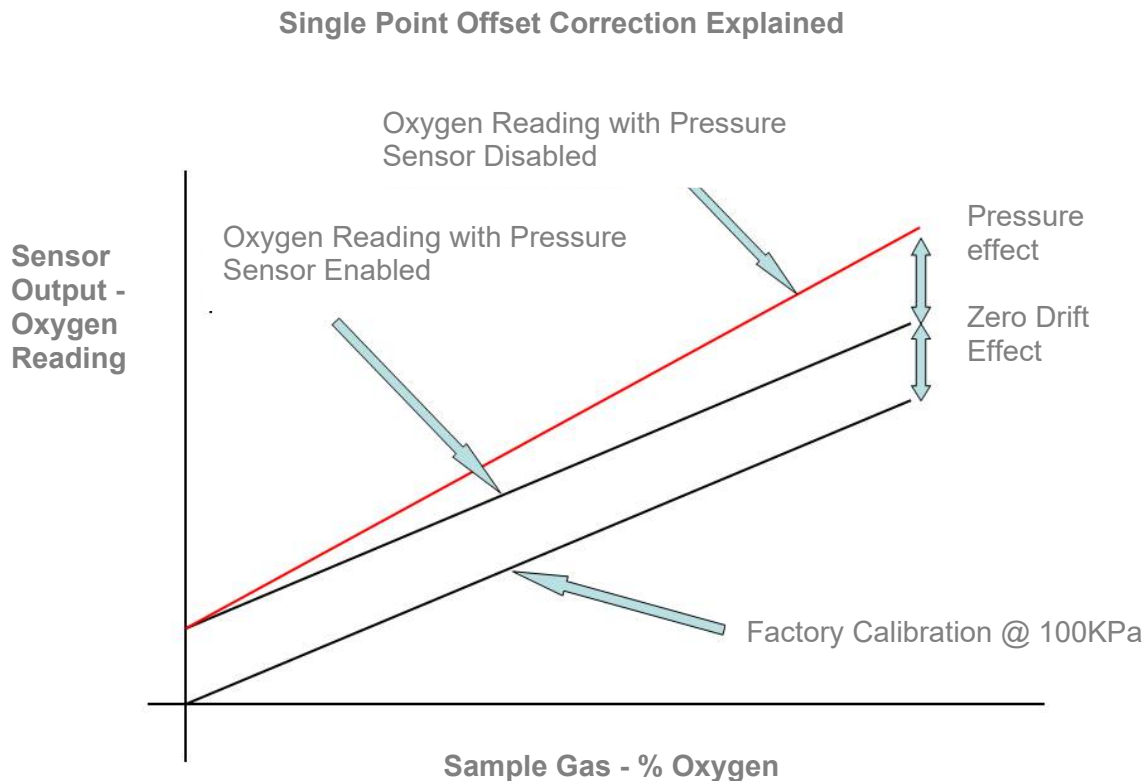


Figure 8

Expose the sensor to a known gas concentration in the range 0.0% O₂ to 100.0% O₂ 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'.



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 No 9.

Caution - No. 10

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 optimize 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, e.g. air (20.9% O₂) 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.

If the pressure of the calibration gas is **NOT** at the same pressure of the previous two-point calibration, errors due to pressure differences must be factored into the host correction, refer to the pressure correction described in method 3, section 4.9.

5.5 Restore Factory Calibration

The sensor can be recovered to its original factory calibration and settings by sending the restore factory calibration backup command. See Table 5 for command set.

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 sensor 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 $-1 < \text{reading} < 1$ 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 sensor 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 Will show 1 st hexadecimal digit of CRC if that option is enabled
10	Unused	Will show 2 nd hexadecimal digit of CRC if that option is enabled Unused if CRC option is disabled
11	Unused	Will show 3 rd hexadecimal digit of CRC if that option is enabled. Unused if CRC option is disabled.
12	Unused	Will show 4 th 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 Hummingbird
	Sensor exposed to extreme temperatures	Return sensor to Hummingbird
E	Sensor is being operated outside of specification or signal levels are unstable	Check environmental operating conditions including physical mount. Ensure gas port is clean and dry. Perform calibration
	Possible liquid or particulate contamination of the diffusion port	If 'E' flag persists return sensor to Hummingbird
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 calibration 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
	Unsuccessful SPOC	Repeat SPOC or a two-point calibration.
S	Calibration in progress	Wait for calibration to complete. A calibration takes approximately 4 seconds

Table 4



5.9 Sample Output Scenarios

The following table shows several 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 Hummingbird
Read status of pressure compensation	!P↵	None	Displays 0 if pressure compensation is disabled or 1 if it is enabled
Enable or Disable Pressure Compensation	!Pn↵	Where n is, 0 to disable pressure compensation 1 to enable pressure compensation	Enables or disables 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 Calibration	!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 Calibration	!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
Read Sensor Identity Code and Configuration Data relevant to Calibration	!D↵	None	In the unlikely event that a calibration procedure fails this command will produce the sensor's calibration data (both latest working and factory back up). This data can be forwarded to Hummingbird technical support should assistance be required
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

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 Variants - without gas ports							
00502701	Y			Y		Y	
00502707				Not Released			
00502715	Y			Y			
00502716	Y				Y		
Face Seal Variants - with piston type seals							
00502721	Y			Y		Y	
00502727				Not Released			
00502735	Y			Y			
00502736	Y				Y		
Bracket Mount Variants - with gas ports							
00502741	Y			Y		Y	
00502747				Not Released			
00502755	Y			Y			
00502756	Y				Y		

Table 7



6.2 Spares

The sensor has no serviceable parts.

Instruction Manual Digital variants, part number **00502001A**

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

Hummingbird 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 Hummingbird reserves the right to charge for replacement.

6.5 Product Failure Out of Warranty

Hummingbird 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 Hummingbird 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 ParacubeTM Sprint.

NOTE – No. 5

Contaminated cells should be disposed of in accordance with the local Environmental and Health & Safety regulations.

Hummingbird reserves the right to refuse to examine products 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 HUMMINGBIRD 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.

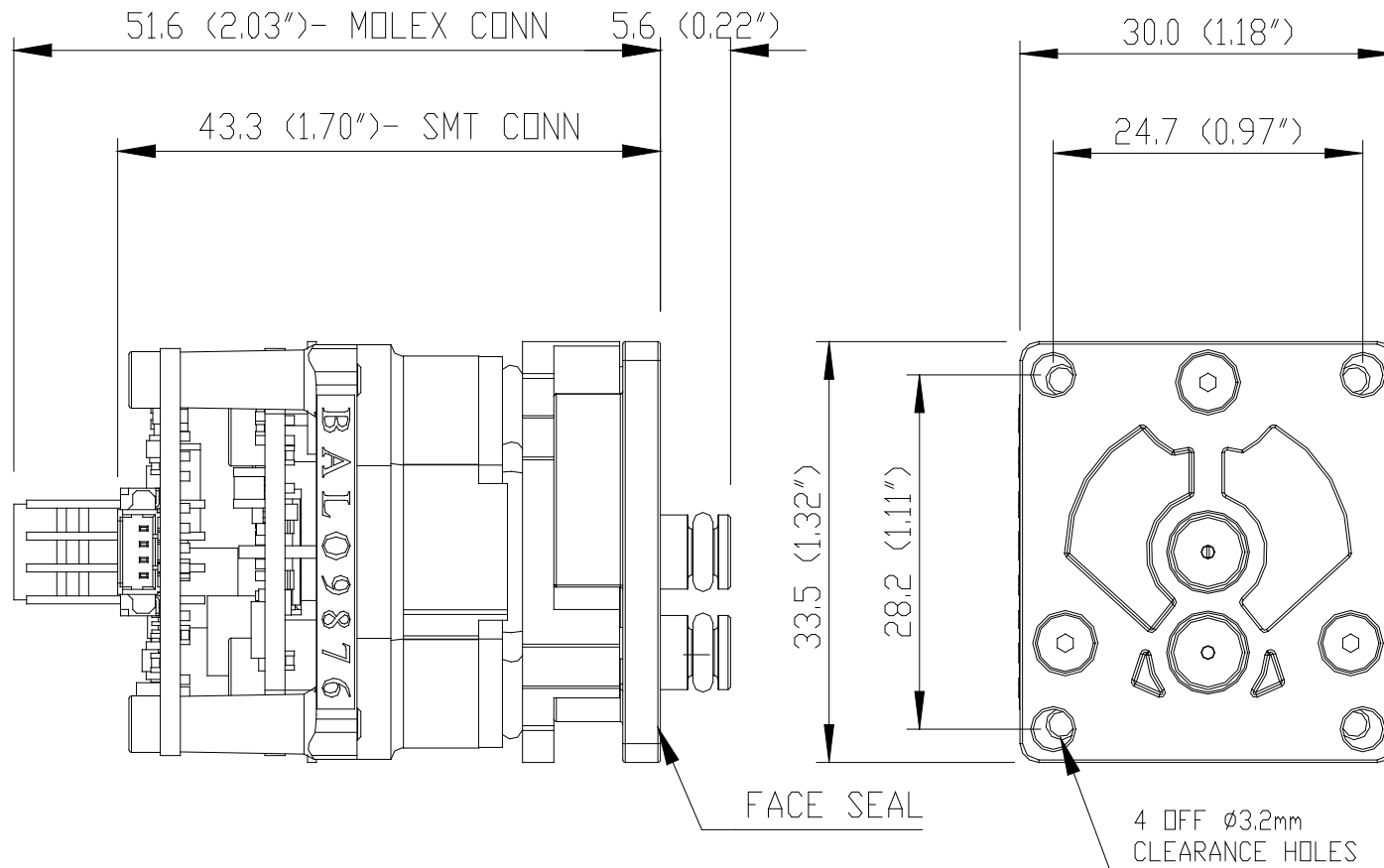
WEEE - The European Waste from Electrical and Electronic Equipment (WEEE) Directive aims to reduce the amount of WEEE going to landfill, by requiring all manufacturers and producers to take responsibility for what happens to the products they sell at the end of their lives. Hummingbird will comply with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

Hummingbird will advise OEMs on how to dispose of components if requested.



7: Appendices

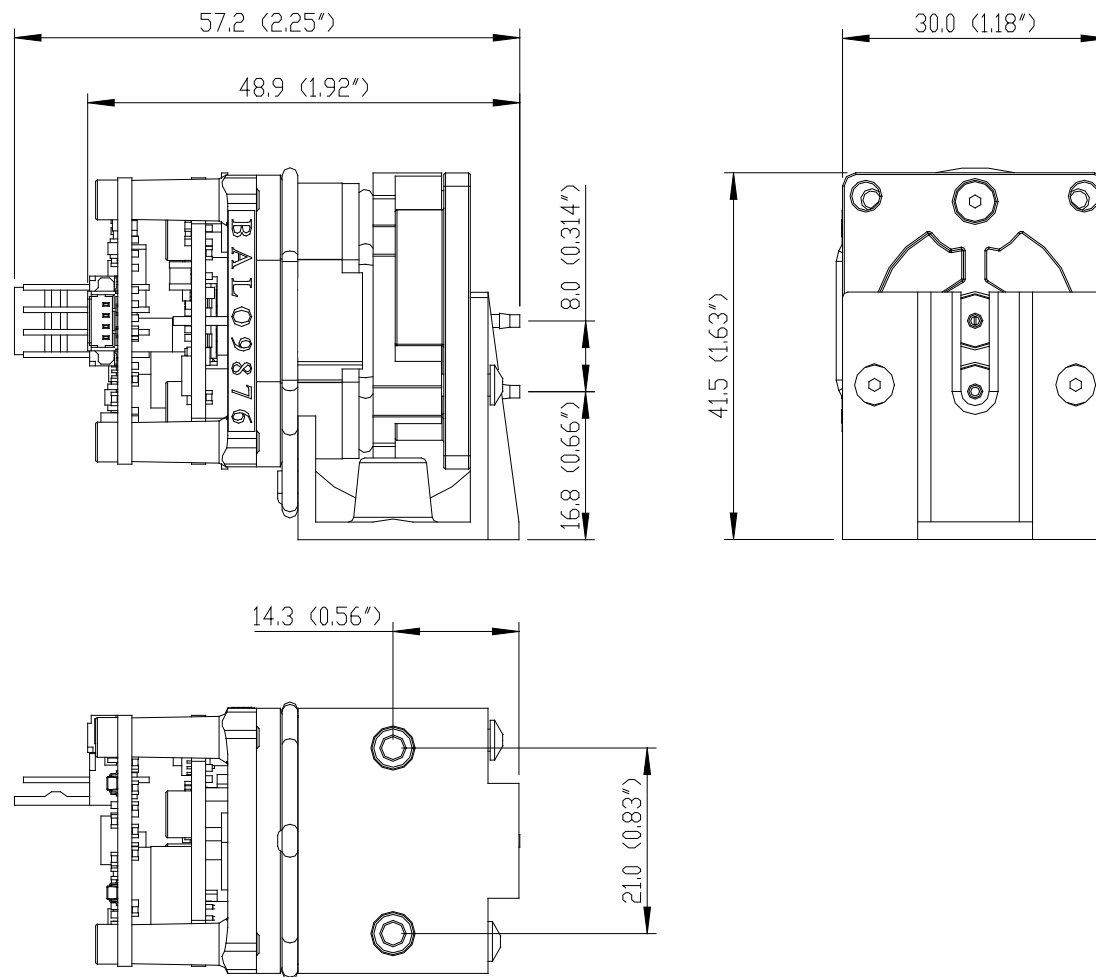
Appendix 7.1 Outline dimensions, face seal with/without gas ports as required





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 ² Hz ⁻¹
Duration:	9 min



Appendix 7.4 Sample Gas Cross Sensitivity Guide

The example below demonstrates how the effect of background gases may be calculated.

Sample gas composition at 50°C.

10% CO₂.
5% CO
5% HCCH
78% N₂

Calculation:

CO ₂	$-0.29 \times 10^{-2} \times 10$	=	-0.029
CO	$0.07 \times 10^{-2} \times 5$	=	0.004
HCCH	$-0.28 \times 10^{-2} \times 5$	=	0.014
N ₂	$0.00 \times 10^{-2} \times 78$	=	0.000
Net background effect		=	-0.039

This offset may be removed during calibration by setting the zero point to +0.039% O₂.

Gas	Formula	$\chi_M \times 10^{-6}$	Zero Error/ % of interfering gas		
			20°C x 0.01%	50°C x 0.01%	60°C x 0.01%
Acetaldehyde	CH ₃ CHO	-22.70	-0.31	-0.34	-0.35
Acetic Acid	CH ₃ CO ₂ H	-31.50	-0.56	-0.62	-0.64
Acetone	CH ₃ COCH ₃	-33.70	-0.63	-0.69	-0.71
Acetylene	HCCH	-20.80	-0.25	-0.28	-0.29
Acrylonitrile	CH ₂ =CHCN	-24.10	-0.35	-0.39	-0.40
Allyl Alcohol	CH ₂ CHCH ₂ OH	-36.70	-0.71	-0.79	-0.81
Ammonia	NH ₃	-18.00	-0.17	-0.19	-0.20
Argon	Ar	-19.60	-0.22	-0.24	-0.25
Benzene	C ₆ H ₆	-54.84	-1.24	-1.36	-1.41
Bromine	Br ₂	-73.50	-1.78	-1.96	-2.02
1,2 Butadiene	C ₄ H ₆	-35.60	-0.68	-0.75	-0.77
1,3 Butadiene	C ₄ H ₆	-30.60	-0.54	-0.59	-0.61
N-Butane	C ₄ H ₁₀	-50.30	-1.11	-1.22	-1.26
Iso-Butane	(CH ₃) ₂ CHCH ₃	-51.70	-1.15	-1.26	-1.30
N-Butyl Acetate	CH ₃ COOC ₄ H ₉	-77.50	-1.89	-2.09	-2.15
Iso-Butylene	(CH ₃) ₂ CH=CH ₂	-44.40	-0.94	-1.03	-1.06
Carbon Dioxide	CO ₂	-21.00	-0.26	-0.29	-0.30
Carbon Disulphide	CS ₂	-42.20	-0.87	-0.96	-0.99
Carbon Monoxide	CO	-9.80	0.06	0.07	0.07
Carbon Tetrachloride	CCl ₄	-66.60	-1.58	-1.74	-1.79
Chlorine	Cl ₂	-40.50	-0.82	-0.91	-0.94
Chloro-Ethanol	ClCH ₂ CH ₂ OH	-51.40	-1.14	-1.25	-1.29



Chloroform	CHCl ₃	-59.30	-1.37	-1.51	-1.55
Cumene	(CH ₃) ₂ CHC ₆ H ₅	-89.53	-2.24	-2.47	-2.55
Cyclohexane	C ₆ H ₁₂	-68.13	-1.62	-1.79	-1.84
Cyclopentane	C ₅ H ₁₀	-59.18	0.35	0.38	0.39
Desflurane	CHF ₂ OC ₂ HF ₄	-84.40	-2.09	-2.37	-2.73
Dichloroethylene	(CHCl) ₂	-49.20	-1.07	-1.18	-1.22
Diethyl Ether	(C ₂ H ₅) ₂ O	-55.10	-1.25	-1.37	-1.41
Enflurane	C ₃ H ₂ F ₅ ClO	-80.10	-1.97	-2.17	-2.57
Ethane	C ₂ H ₆	-26.80	-0.43	-0.47	-0.49
Ethanol	C ₂ H ₅ OH	-33.60	-0.62	-0.69	-0.71
Ethyl Acetate	CH ₃ COOC ₂ H ₅	-54.20	-1.22	-1.34	-1.39
Ethyl Chloride	C ₂ H ₅ Cl	-46.00	-0.98	-1.08	-1.12
Ethylene	C ₂ H ₄	-18.80	-0.20	-0.22	-0.22
Ethylene Glycol	(CH ₂ OH) ₂	-38.80	-0.77	-0.85	-0.88
Ethylene Oxide	(CH ₂) ₂ O	-30.70	-0.54	-0.60	-0.61
Freon 11	CCl ₂ F ₂	-52.20	-1.16	-1.28	-1.32
Freon 12	CCl ₃ F	-58.70	-1.35	-1.49	-1.53
Freon 113	CHCl ₂ CH ₂ Cl	-66.20	-1.57	-1.73	-1.78
Freon 114	C ₂ Cl ₂ F ₄	-77.40	-1.89	-2.08	-2.15
Furan	C ₄ H ₄ O	-43.09	-0.90	-0.99	-1.02
Halothane	C ₂ HBrClF ₃	-78.80	-1.93	-2.13	-2.19
Helium	He	-1.88	0.29	0.32	0.33
N-Heptane	C ₇ H ₁₆	-85.24	-2.12	-2.33	-2.40
N-Hexane	C ₆ H ₁₄	-73.60	-1.78	-1.96	-2.02
Hydrogen	H ₂	-3.98	0.23	0.26	0.26
Hydrogen Chloride	HCl	-22.60	-0.31	-0.34	-0.35
Hydrogen Sulphide	H ₂ S	-25.50	-0.39	-0.43	-0.44
Isoflurane	C ₃ H ₂ F ₅ ClO	-80.10	-1.97	-2.17	-2.24
Krypton	Kr	-28.80	-0.49	-0.54	-0.55
Methane	CH ₄	-17.40	-0.16	-0.17	-0.18
Methanol	CH ₃ OH	-21.40	-0.27	-0.30	-0.31
Methyl Acetate	CH ₃ COCH ₃	-42.60	-0.88	-0.97	-1.00
Methyl Ethyl Ketone	CH ₃ COCH ₂ CH ₃	-45.50	-0.97	-1.07	-1.10
Methyl Isobutyl Ketone	C ₄ H ₉ COCH ₃	-69.30	-1.66	-1.82	-1.88
Monochlorobenzene	C ₆ H ₅ Cl	-70.00	-1.68	-1.85	-1.90
Nitric Oxide	NO	1461.00	42.56	42.96	42.94
Nitrogen	N ₂	-12.00	0.00	0.00	0.00
Nitrogen Dioxide	NO ₂	150.00	5.00	16.00	20.00
Nitrous Oxide	N ₂ O	-18.90	-0.20	-0.22	-0.23
N-Octane	C ₈ H ₁₈	-96.63	-2.45	-2.70	-2.78
Oxygen	O ₂	3449.00	100.00	100.00	100.00
Ozone	O ₃	6.70	0.54	0.60	0.61
Iso-Pentane	C ₅ H ₁₂	-64.40	-1.51	-1.67	-1.72
Phenol	C ₆ H ₅ OH	-60.21	-1.39	-1.54	-1.58
Propane	C ₃ H ₈	-38.60	-0.77	-0.85	-0.87
Iso-Propanol	(CH ₃) ₂ CHOH	-47.60	-1.03	-1.13	-1.17
Propylene	C ₃ H ₆	-31.50	-0.56	-0.62	-0.64
Isopropyl Ether	(CH ₃) ₄ CHOCH	-79.40	-1.95	-2.15	-2.21



Pyridine	$\text{N}(\text{CH})_5$	-49.21	-1.08	-1.19	-1.22
Styrene	$\text{C}_6\text{H}_5\text{CH}=\text{CH}_2$	-68.20	-1.62	-1.79	-1.85
Sevoflurane	$\text{CFH}_2\text{OCH}(\text{CF}_3)_2$	-111.20	-2.86	-3.15	-3.25
Sulphur Dioxide	SO_2	-18.20	-0.18	-0.20	-0.20
Tetrachloroethylene	$\text{Cl}_2\text{C}=\text{CCl}_2$	-81.60	-2.01	-2.22	-2.28
Tetrahydrofuran	$\text{C}_4\text{H}_8\text{O}$	-52.00	-1.16	-1.27	-1.31
Toluene	$\text{C}_6\text{H}_5\text{CH}_3$	-66.11	-1.56	-1.72	-1.78
Vinyl Chloride	$\text{CH}_2=\text{CHCl}$	-35.60	-0.68	-0.75	-0.77
Xenon	Xe	-43.90	-0.92	-1.02	-1.05
Xylene	$(\text{CH}_3)_2\text{C}_6\text{H}_4$	-77.78	-1.90	-2.09	-2.16



Appendix 7.5 RoHS II Directive 2011/65/EU Declaration



Servomex Material Declaration - RoHS II (2011/65/EU)

Equipment covered by this declaration

Paracube 1st & 2nd Generation

Micro, Modus & Sprint - all variants

Equipment serial numbers covered by this declaration Database records from 5th November 2013

Under the EU RoHS II Directive (2011/65/EU), electrical and electronic equipment included within its scope shall not contain any of the following substances at above the given MCV (Maximum Concentrations Values), unless the application is included in a valid and current exemption listed in Annex III or IV of the Directive:

Restricted substance	MCV (% by weight of a homogeneous material)	Restricted substance	MCV (% by weight of a homogeneous material)
Lead	0.1	Hexavalent chromium	0.1
Mercury	0.1	Polybrominated biphenyls (PBB)	0.1
Cadmium	0.01	Polybrominated diphenyl ethers (PBDE)	0.1

Management Systems (Servomex Technical Centre, Crowborough, England)

Quality: ISO 9001:2015

Environmental: ISO 14001:2015

Servomex declares that the equipment covered by this declaration does not contain any of the substances restricted by the RoHS II Directive (2011/65/EU) at above the given MCVs

Servomex has relied upon information provided by suppliers in completing this declaration which may or may not have been independently verified by a third party. However, where the information has not been independently verified, as a minimum, it is continually assessed to Servomex's internal RoHS process QMS-4415 set up in accordance with Servomex Management Systems.

C R Edwards

5th March 2020

C. Edwards, Hummingbird Technical Manager

Dated: 5th March 2020

Servomex Group Ltd, Jarvis Brook, Crowborough, East Sussex, England. TN6 3FB

Hummingbird Declaration HB-Dec-004_0

A Spectris company. Registered office: Jarvis Brook, Crowborough, East Sussex, TN6 3FB

L40017001-00010



Appendix 7.6 REACH Directive EC1907/2006 Declaration

SERVOMEX 

 **Hummingbird**
SENSING TECHNOLOGY

Servomex Material Declaration – Compliance with REACH, 1907/2006

Equipment covered by this declaration	Paracube 1 st and 2 nd generation Micro, Modus and Sprint – all variants
Equipment serial numbers covered by this declaration	Database records dating back to 14 th Dec. 2013

Annex XIV substances

Hummingbird declare that to the best of our knowledge the Equipment Type referenced above does not contain any of the substances or preparations listed in this annex.

Annex XVII substances

Hummingbird declare that to the best of our knowledge the Equipment Type referenced above does not contain any of the substances listed in this annex unless their use is in accordance with the restrictions of use given in REACH.

Substances of Very High Concern (SVHCs)

Hummingbird declare that to the best of our knowledge the Equipment Type referenced above does not contain any of the substances listed in this annex at a concentration of 0.1 % weight by weight (w/w) or above.

Management Systems (Servomex Technical Centre, Crowborough, England)

Quality: ISO 9001:2015

Environmental: ISO 14001:2015

Servomex declares that the equipment covered by this declaration comply with requirements of REACH, 1907/2006 and are continually assessed against the latest candidate list as reported by ECHA (European Chemicals Agency).

Servomex has relied upon information provided by suppliers in completing this declaration which may or may not have been independently verified by a third party. However, where the information has not been independently verified, as a minimum, it is continually assessed to Servomex's internal REACH process QMS-4416 set up in accordance with Servomex Management Systems.


C R Edwards

5th March 2020


C. Edwards, Hummingbird Technical Manager

Dated: 5th March 2020

Hummingbird Declaration HB-Dec-003_0

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Ref No.	Page(s) Affected	Summary of Change	Changed by	Approved by
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Hummingbird SENSING TECHNOLOGY

Technical and Service Centre,
Jarvis Brook, Crowborough,
East Sussex, TN6 3FB, UK

Tel: +44 (0) 1892 652 181
Fax: +44 (0) 1892 662 253
info@hummingbirdsensing.com

EMEA, RUSSIA & INDIA

Scott Gordon

Sales Manager

Servomex Technical Centre
Jarvis Brook
Crowborough
East Sussex
TN6 3FB
UNITED KINGDOM

Mob: +44 (0)7920 827 493
sgordon@
hummingbirdsensing.com

AMERICAS

Louis Gansky

OEM Strategic Account Manager

Servomex Americas
Business Center
12300 Dairy Ashford
Suite 400
Sugar Land
TX 77478
USA

Mob: +1 (281) 221 3548
lgansky@
hummingbirdsensing.com

JAPAN & KOREA

佃 昌樹 Masa Tsukuda

OEM Strategic Account Manager

Servomex Division
Spectris Co. Ltd
3/F Kawasaki Nisshincho Bldg.
7-1 Nisshin-cho, Kawasaki-ku
Kawasaki-Shi, Kanagawa
210-0024
JAPAN

Tel: +81 (0)44 589 3390
Mob: +81 (0)80 3759 1644
mtsukuda@
hummingbirdsensing.com

CHINA

张志丽 Lisa Zhang

OEM Strategic Account Manager

Servomex Asia Pacific
Business Centre
Beijing Office Rm. F908,9F
Ruida Building
No. 74 Lulu Road
Shijingshan District
Beijing
CHINA

Mob: +86 139 1073 7814
lisazhang@
hummingbirdsensing.com

www.hummingbirdsensing.com

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