The purpose of this manual is to explain how to order the correct AFE, how to connect power and take readings and mount the circuit board. Correction for zero currents is a separate document.

1 Ordering the correct circuit board and integrating with your circuits

The AFE circuit is designed for use only with Alphasense A4 family of four-electrode gas sensors. The AFEs use low noise components and in order to achieve good resolution; use best practice for grounding and screening. You must take time to optimise your EMC environment to a low level to achieve low ppb resolution.

The AFE includes a low noise bandgap to provide a 200 mV bias voltage for NO sensors and can measure both oxidising (CO, H_2S, NO, SO_2) and reducing (O_3, NO_2) gas sensors.

The AFE family is configured as three types, depending on the number of sensors you require: two A4 sensors, three A4 sensors or three A4 sensors plus PID. Within each type there are several circuit variations to accept the different sensors (labelled as SN1, SN2, SN3), below:

2-way A4 AFE	**SN1**	**SN2**	
810-0021-00	NO2	O3	
810-0021-01	NO2 or O3	NO	
810-0021-02	NO2 or O3	CO or SO2 or H2S	
810-0021-03	NO	CO or SO2 or H2S	
810-0021-04	CO	SO2 or H2S	
3-way A4 AFE	**SN1**	**SN2**	**SN3**
810-0019-00	NO2	O3	CO or SO2 or H2S
810-0019-01	NO2	O3	NO
810-0019-02	NO2	CO	SO2 or H2S
810-0019-03	NO2	CO or SO2 or H2S	NO
810-0019-04	CO	SO2	H2S
3 x A4 +PID	**SN1**	**SN2**	**SN3**
810-0020-00	NO2	O3	CO or SO2 or H2S
810-0020-01	NO2	O3	NO
810-0020-02	NO2	CO	SO2 or H2S
810-0020-03	NO2	CO or SO2 or H2S	NO
810-0020-04	CO	SO2	H2S

Table 1. Part numbers for the three types of AFEs and their sensor options

Ensure your AFE is configured correctly for your A4 sensors if the AFE has been supplied separate from the sensors.

The circuit uses one op amp to provide balance current into the counter electrode. Both the working electrode (*WE*) and auxiliary electrode (*Aux*- used to compensate for zero current) have equivalent two stage amplifiers: the first stage is a high gain transimpedance amplifier and the second buffer stage allows for inverting sensor signals for NO_2 and O_3 sensors. Both signals are available on the 10 or 12 way connector as separate pairs.

A Pt 1000 temperature sensor is included on a separate PCB, perpendicular to the AFE to ensure that temperature compensation is accurate. There are no adjustments on the AFE. The offset voltages are recorded on the calibration sheet included with the AFE. The electronic gain is also fixed and is accurate ±1%.

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2 Connecting power and taking readings

The socket for power and signals is shown in figure 1 below.
The PCB socket is a Toby Electronics 10-way polarised socket, part no. C05-10-A-G-1. (810-0021, 810-0019) or Toby Electronics 12-way polarised socket, part no. C05-12-A-G-1 (810-0020).

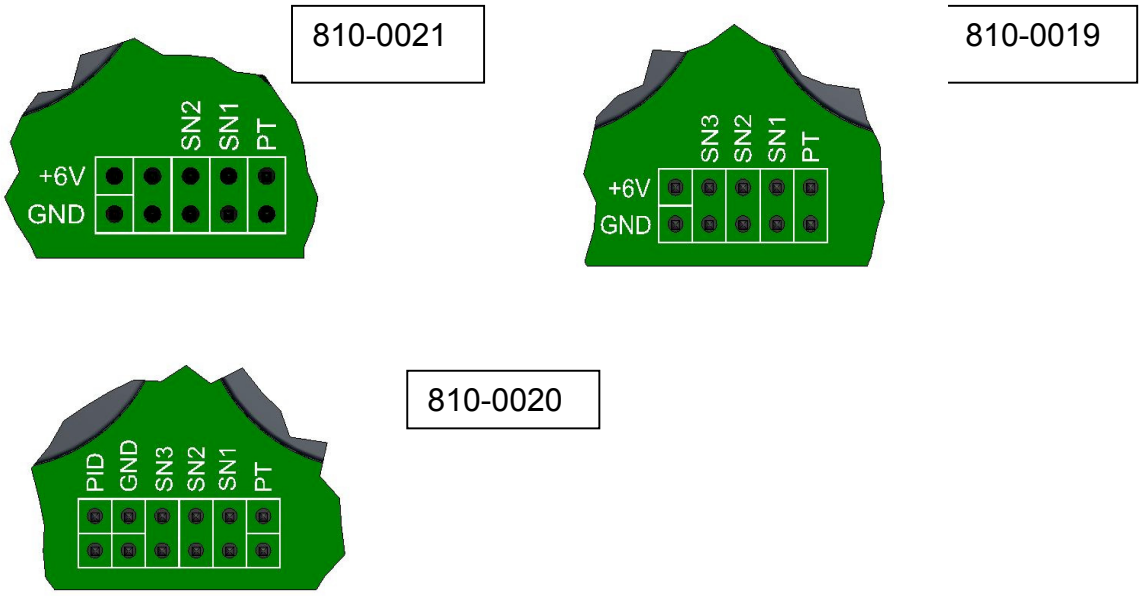

Figure 1. AFE socket pinouts for power and signals for 810-021 (2 sensor), 810-0019 (3 sensors) and 810-0020 (3 sensors plus PID)

Power

DC power must be between 3.5 and 6.5 VDC. Ensure your power supply is low noise and decoupled, or its noise component will be added to the measured signal. Required power is 1.5mA (810-0021), 2mA (810-0019) and 35mA (810-0020- this includes the PID, which is powered separately).

Outputs from the working and auxiliary electrodes are buffered DC signals so a normal A/D converter will be fine, so long as it does not inject noise back into the AFE. If you are concerned about noise injection, then decouple using 10nF plus 100nF capacitors close to the connector.

Noise

1 These gas sensors are very sensitive to gas and are also very susceptible to EMC pickup. Ideally the sensors would be housed in a Faraday cage, but this is not normally practicable, so shield and ground as best you can. Nearby digital circuits can also disrupt the signal quality.

2 Typical noise at Alphasense, when calibrating on a bench without additional shielding, but with good power supply is three mV (p-p). Digital averaging can reduce this to less than one mV, equivalent to typically 2 ppb. Further reduction of noise can be achieved by shielding.

3 It is important to decouple your power supply and A/D converter from the AFE. Since the 0V line is shared by the power supply and output, any noise injected by your power supply or reading circuit will appear on the measured signal. We recommend using two decoupling capacitors close to the socket: 10nF and 100nF.

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Cables

Cables are available from Alphasense. These are ribbon cables in two lengths: the shorter length is for direct connection to a main board and the longer length is useful for laboratory testing and in housings where the AFE-main board distance is longer. Cables are provided with a spare header for convenience. Table 2 below defines cable options. The IDC headers on the cable ends are Toby Electronics part number A05-10-BSA1-G (10 way) and Toby Electronics part number A05-12-BSA1-G (12 way).

Cable	Description	NOTES
000-CBLE-00	10 Way IDC Cable (50mm) for 2/3 Sensor AFE	With two polarised sockets
000-CBLE-01	10 Way IDC Cable (200mm) for 2/3 Sensor AFE	With two polarised sockets
000-CBLE-02	12 Way IDC Cable (50mm) for 4 Sensor AFE	With two polarised sockets
000-CBLE-03	12 Way IDC Cable (200mm) for 4 Sensor AFE	With two polarised sockets

Table 2. Alphasense AFE board cable options. For other lengths, contact Alphasense.

3 Mounting the circuit board

The mounting hole locations and diameters are shown in Appendix 1.

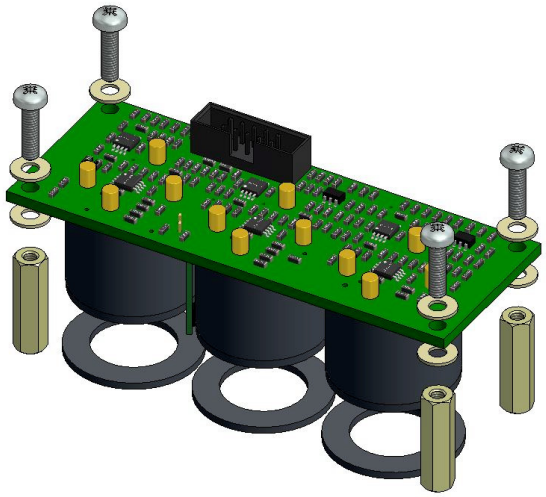

Figure 2. AFE fitting with optional mounting kit

An optional **AFE Fitting Kit** can be purchased. The kit can be used with all AFEs.
Order part number **000- 0AFE-KIT**. Figure 2 shows the correct fitting method.
The kit includes:

4x	pillars	16.0 mm length, M2.5 tapped, brass
8x	washers	M2.5: fits on both sides of AFE to achieve 16.5 mm pillar height and protect screw-PCB
4x	screws	M2.5 x 10 (Pozi-screw, Zinc plated)
4x	foam seal	Adhesive backed. Optional use.

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4 Temperature measurement

The Pt1000 is a Platinum Resistance Temperature Detector (RTD), conforming to IEC 60751:2008, which is the standard temperature/ resistance table, following the standard 0.00385 ohm/ ohm/ K temperature dependence. The temperature sensor should be in thermal contact with the top of the center A4 sensor so that it tracks the temperature at the top of the sensor for accurate temperature compensation. See figure 3 below. Thermally conductive paste is recommended.

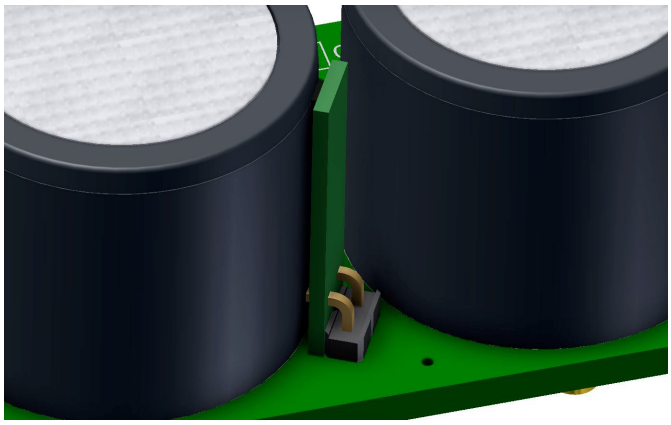

Figure 3. Correct location of Pt1000 and A4 sensor in intimate contact.

Note that there is no temperature compensation on the AFE circuit: it only allows you to measure the temperature and then you apply your correction algorithm (as explained in a separate document). For ease of use, the Pt 1000 is electrically connected to the precision 2.5V internal reference with an in-line 7320 Ω load resistor. The Pt(-) (ground end of the Pt 1000) is not connected, so you have two options:

1 Connect the Pt(-) pin to the analogue ground on your main circuit board and measure the voltage on pin Pt(+) to determine temperature. Pt 1000 current is about 300 µA.
2 Remove the 7320 ohm load resistor (labelled RL/ PT) and connect your own resistance measuring circuit between the two Pt 1000 pins.

If you wish to use option 1, which is measuring the internally generated temperature dependent voltage, then to calculate the temperature, the transfer equation is:

$$V= 0.297(V_{20C}) +0.0010 *(T-T_{20C})$$

The offset voltage is approximately 300mV at 20C: this will vary due to resistor errors, Pt 1000 variability, AFE bandgap voltage and your A/D offset errors, so you will need to calibrate the voltage at ambient temperature. This sensitivity of 1.0 mV/ K does not need calibration; only the initial room temperature offset needs calibration. This initial calibration will normally be a software setting of your display to show the ambient temperature.

Since Pt RTDs are not perfectly linear, figure 4 below shows the non-linearity error if the sensor is calibrated at 20ºC. If you wish better accuracy then software correction of the error curve is normal.

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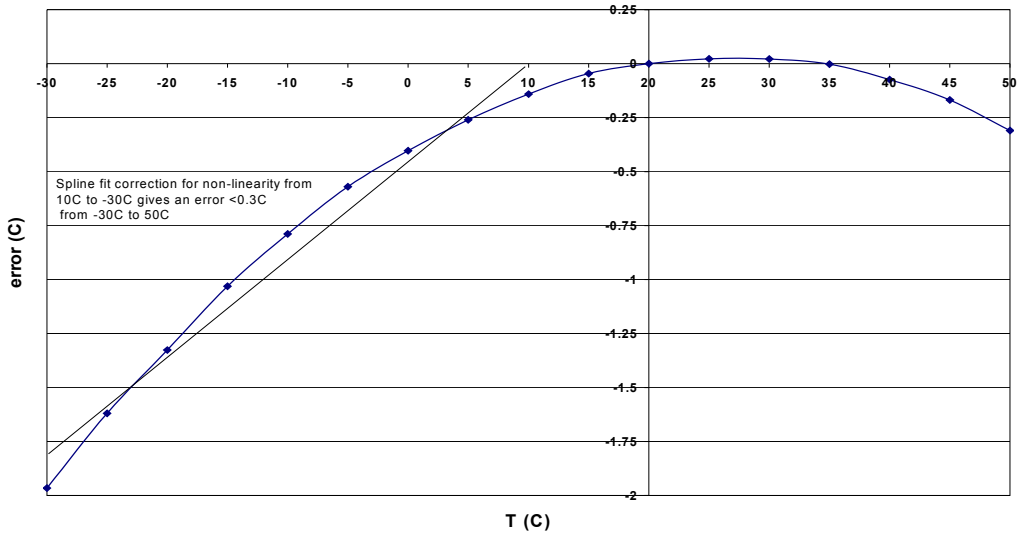

Figure 4. Non-linearity for Pt 1000 when using internal voltage reference. Spline fit in software significantly improves accuracy at low temperatures.

If you wish to measure the Pt 1000 resistance separately, then connect a resistance measuring circuit across the two Pt 1000 pins after removing the load resistor (labelled RL/PT). Since the resistance is 1000 ohms (0ºC), a two-wire measurement circuit is adequate. The current through the sensor should be less than 500 µA to avoid sensor self-heating.

5 Use with a PID (810-0020)

AFE part number 810-0020 includes a fourth socket to accept the Alphasense PID. Since most applications will be measuring low concentrations of gases and VOCs, the PID-AH is recommended. You will be asked to specify whether the on-board voltage regulator in the PID is enabled; since the AFE requires more than 3.5V, you should specify regulator enabled. If you received the PID with regulator disabled, then adding a solder blob to the circuit base (as explained in the PID manual) will enable the regulator.

The PID has three pins, but the ground pin is connected with the other ground pins on the AFE. The output and power supply are separate and do not share any circuitry with the rest of the AFE because it is normal to power continuously the A4 sensors but to save power, many users only pulse the PID since it requires 30mA to operate and 120mA for the first 200 ms to tune the circuit when powered on. If you wish to pulse the PID, then:

Switch on for 10 seconds, measure for 1 second and software smooth the reading, then switch off. You can leave the PID switched off for the rest of your sampling cycle, but when the PID is switched off, VOCs and particulates may collect on the lamp surface so when you switch on the PID, it must initially clean the surface and you will observe an initial cleaning peak which may take a few minutes, depending on the air being sampled and time the PID was off. We recommend 30 second to two minute cycle time to minimise this problem of cleaning at switch-on, If you are only measuring every 30 or 60 minutes, then allow the PID at least one minute before taking a reading. Cycling the PID does not reduce lamp lifetime.

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6 Calibration

Each AFE is shipped with a calibration sheet, defining the zero offsets and sensor sensitivity. Table 3 below shows typical values for A4 sensors on AFE boards. All zero recordings are in mV. The circuitry for the three types of AFEs are the same, so this is typical of the 0019, 0020 and 0021 AFE PCBs.

mV	CO-A4	H2S-A4	NO-A4	NO2-A4	O3-A4	SO2-A4
WE electronic zero	275	315	310	305	370	277
WE sensor zero (23ºC)	-8	-2	8	1	10	1
Total WE zero	267	313	318	306	380	278
Aux electronic zero	273	330	325	310	365	270
Aux sensor zero (23ºC)	-3	-3	10	2	-25	14
Total Aux zero	270	327	335	312	340	284
WE average sensitivity (nA/ ppb)	0.3	1.48	0.34	-0.38	-0.3	0.4
AFE electronic gain (mV/ nA)	0.8	0.8	0.8	-0.73	-0.73	0.8
WE average sensitivity (mV/ ppb)	0.24	1.184	0.272	0.2774	0.219	0.32
Full scale (ppm) at 6.0V	27	5	24	23	30	20

Table 3. Typical calibration results for A4 sensors on AFEs.

The zero voltages for the working electrode (WE) and Auxiliary electrode (Aux: also termed fourth electrode) have been measured carefully. Each measurement is explained:

WE/ Aux electronic zero: This is the offset voltage which is purposely offset from 0V. This voltage is due only to the electronics and will remain approximately constant for the lifetime of the AFE. This excludes any additional offset errors introduced by your electronics (eg A/D converter, additional buffer amps). This zero does not change with temperature by more than 1 or 2 mV from –30 to +50ºC.

WE/ Aux sensor zero: Although the sensor offset is a current, the AFE transimpedance amp translates this current into a voltage. This offset is important: the Alphasense Zero Calibration Instructions explain how to use this offset and its temperature dependence for both te WE and Aux to correct the zero at other temperatures.

Total WE/ Aux zero: The sum of the electronic and sensor zeros, this is the voltage that should be subtracted in software before calculating the gas concentration. This zero must be corrected for sensor zero temperature dependence if the measurement temperature is not within ±4ºC of 23ºC.

WE sensitivity (nA/ ppm): Sensitivity is measured at low concentrations: between 500 ppb and 2 ppm, as specified in the Technical Data Sheet for that sensor.

PCB gain (mV/ nA): AFE circuits use a transimpedance and buffer amp, which together define the AFE circuit gain. This gain is fixed and is not adjustable. Gain is repeatable ±3%. Note that the gases that generate a negative current (NO_2, O_3) use an inverter amp buffer stage in the AFE so the output is positive, not negative.

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WE sensitivity (mV/ ppb): Simply the sensitivity in nA/ ppb, multiplied by the PCB gain. After correcting for the zero offset, multiply the measured mV by this constant to obtain concentration as ppb gas.

7 Recalibration

The AFE with sensor calibration has been measured before leaving the factory, but environmental conditions and sensor drift mean that periodic checking of the calibration may be required. Also, at low ppb concentrations both temperature and humidity will affect the offset voltage of both the WE and Auxiliary electrodes.

Gain/ sensitivity correction

Unless you have access to an accurate gas supply, it is advised to return (sensors + AFE) to Alphasense for zero and gain recalibration. If you wish to check calibration then:

- Use certified gas bottle with concentration between 1 and 10 ppm, balance air or nitrogen
- Use FEP, PFA or other fluoropolymer tubing
- Use short tubing lines and avoid excessive connections
- If testing the AFE separate from you instrument housing, Alphasense offers gas hoods for ppb measurements (appendix 2).
- If testing sensors in your housing then ensure your gas hood is sealed tight.
- Beware that some components in your housing may outgas (eg silicone strip connectors, gaskets), leading to high background readings; these are difficult to eliminate and the normal solution is to change to low outgas adhesives, seals, rings.
- Purge the lines for at least 20 minutes of the calibration gas before testing.
- Ensure a test air flow rate over each sensor of 500sccm (0.5L/ min) or more.

8 Problems and support

Should you encounter problems of sensor performance or reliability then contact Alphasense by email:
sensors@aslphasense.com

End of User Manual

Attached: Appendix 1, 2

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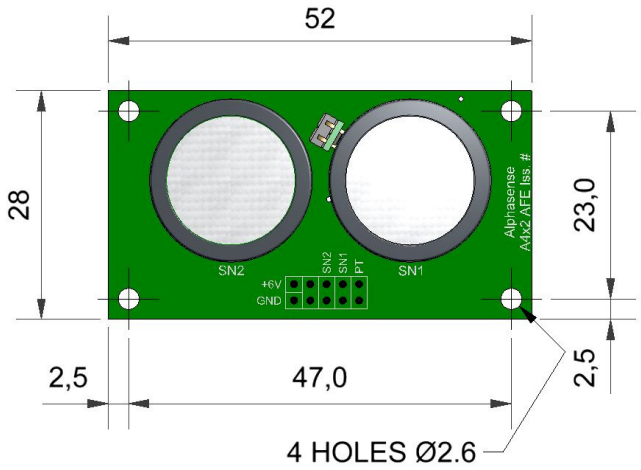
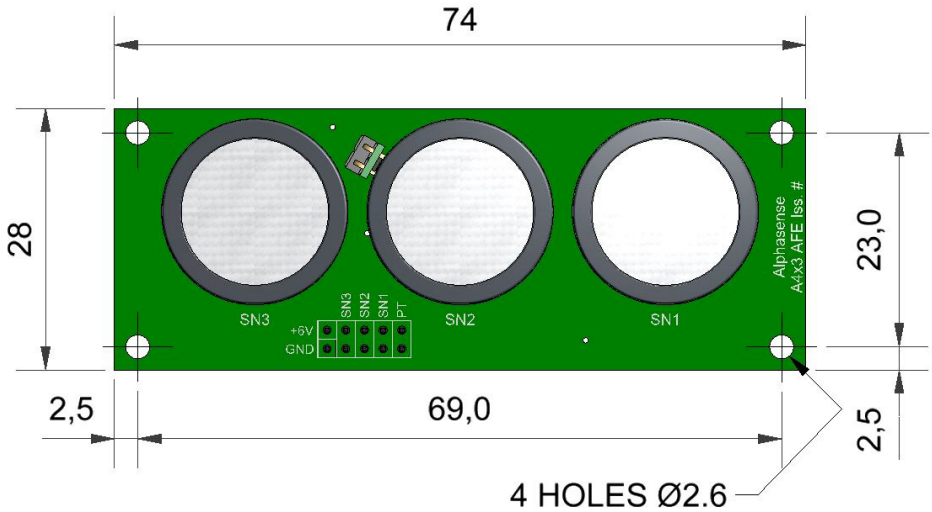
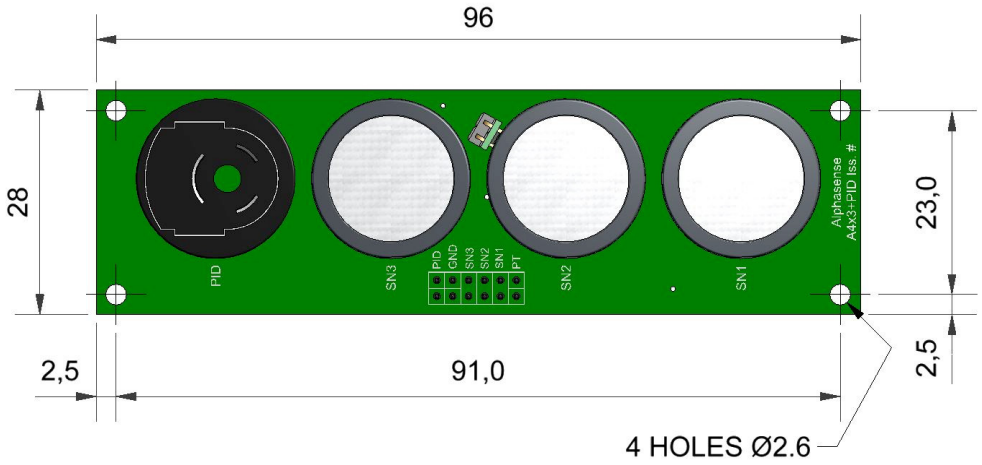
Appendix 1. AFE board and mounting hole dimensions and locations







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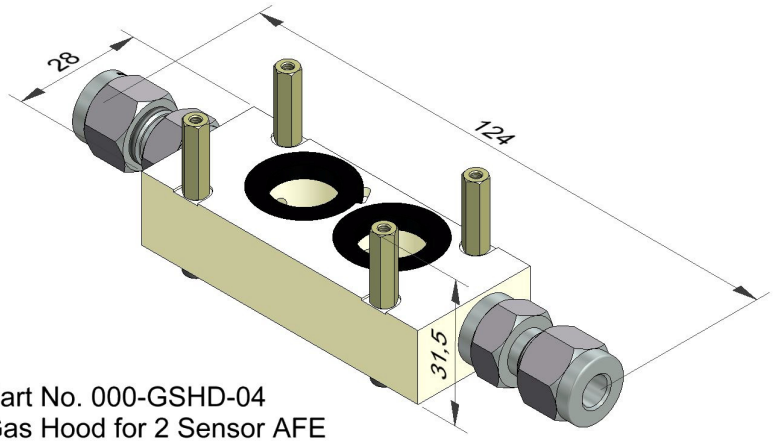
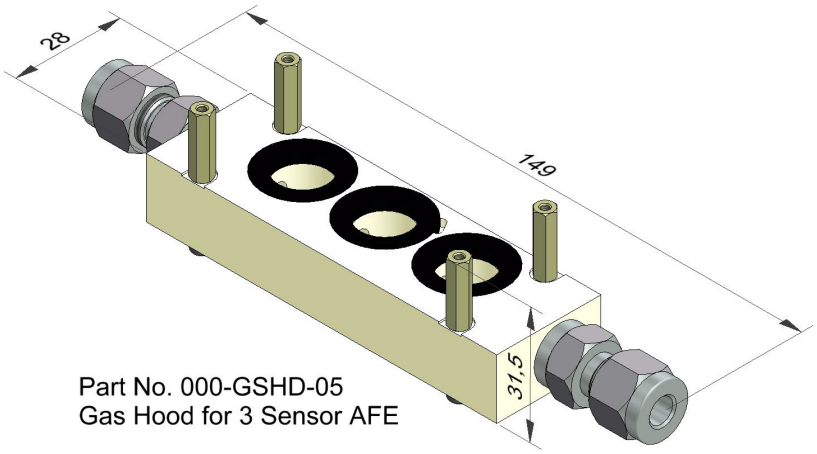
Appendix 2. Calibration gas hood options with Swagelok connectors



Part No. 000-GSHD-04
Gas Hood for 2 Sensor AFE



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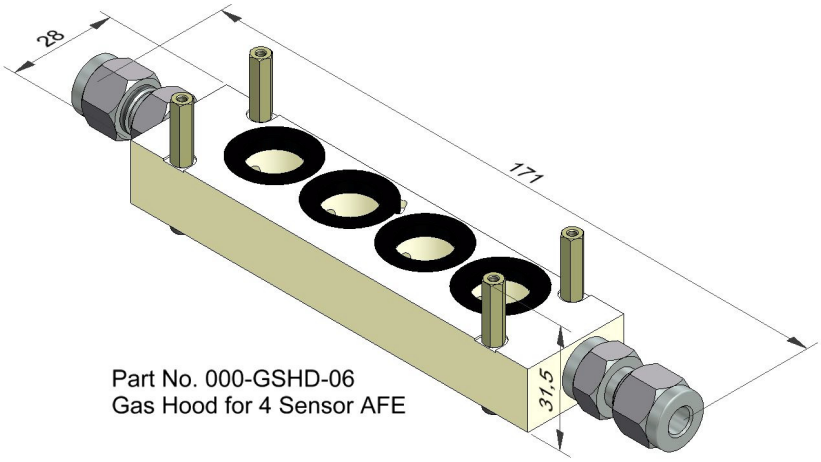
Gas Hood for 3 Sensor AFE



Part No. 000-GSHD-06
Gas Hood for 4 Sensor AFE

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