5S MkIII CO2 Sensor

OEM User Manual

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List of Contents

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1 Introduction

This manual is of a more technical nature than the standard 5S3 User Manual (5S3-800-xx). It is intended for the OEM user of the 5S3 who will wish to better understand the sensor and be able to configure some of the options.

It also covers the oxygen sensor option of the 5S3.

It is a general 5S3 OEM User Manual and as such not all the information in here may be relevant to your sensor part number.

1.1 Safety warnings

1.1.1 Standard (alkaline) oxygen cell

The oxygen sensor contains a potassium hydroxide (KOH) electrolyte. The cells are sealed by a membrane but severe mistreatment such as rapid decompression can cause leakage.

If there are any signs of chemical leakage from either the sensor assembly or from replacement cells, use rubber gloves and wear chemical splash goggles to handle and clean up. Thoroughly rinse contaminated surfaces with water.

Note the First Aid Procedures below to be adopted in the event of contact with leaks of the sensor electrolyte.

First Aid Procedures

CONTACT TYPE	EFFECT	FIRST AID PROCEDURE
Skin	KOH electrolyte is corrosive. Skin contact could result in a chemical burn.	Wash the affected parts with a lot of water and remove contaminated clothing. If stinging persists get medical attention.
Ingestion	Can be harmful or FATAL if swallowed	Drink a lot of fresh water. Do not induce vomiting. Get medical attention immediately.
Eye	Contact can result in the permanent loss of sight	Get medical help immediately and continue to wash with a lot of water for at least 15 minutes

1.1.2 Acid oxygen cell

The oxygen sensor contains a weak acid. The cells are sealed by a membrane but severe mistreatment such as rapid decompression can cause leakage.

If there are any signs of chemical leakage from either the sensor assembly or from replacement cells, use rubber gloves and wear chemical splash goggles to handle and clean up. Thoroughly rinse contaminated surfaces with water.

First Aid Procedures in the event of contact with leaks of electrolyte are as above.

1.2 Handling precautions for the 5S3

The circuit boards within the enclosure are static sensitive and must be handled accordingly.

Care must also be taken not to touch the white gel that protects the pressure sensor.

The maximum rate of change of pressure that the unit should be exposed to is 2 bar / minute.

If the oxygen cell is exposed to temperatures below -10°C it may suffer a permanent change in output and require re-calibration.

1.3 Glossary of abbreviations

5S3	Third generation Analox CO_2 sensor
ADC	Analogue to Digital Converter
ASST	Analox Sensor Setup Tool
bar	Unit of pressure, one standard atmosphere is 1.01325 bar
CO_2	Carbon dioxide
CRC	Cyclic redundancy check (a technique for determining if a data packet has been corrupted)
CSV	Comma Separated Variables
DAC	Digital to Analogue Converter
DDB	Direct Digitisation Bench (an umbrella name for the 5S3 and MIR)
EEPROM	Electrically Erasable Programmable Read Only Memory (a type of non volatile memory used to store configuration data)
IEEE	Institute of Electrical and Electronic Engineers
IR	Infra Red
KOH	Potassium Hydroxide
LED	Light Emitting Diode
mbar	Unit of pressure equal to one thousandth of a bar
MEC	Mini Electrochemical Cell (a flexible electronics and hardware platform that interfaces with a variety of electro-chemical cells, PID sensors and bridge output sensors)
MIR	Mini Infra Red sensor (miniature version of the third generation Analox CO_2 sensor)
NDIR	Non Dispersive Infra Red
O_2	Oxygen
OEM	Original Equipment Manufacturer
PC	Personal Computer
PID	Photo-Ionization Device
PLC	Programmable Logic Controller
ppm	Parts Per Million
ppmSEV	ppm equivalent at the surface (this is a measure of partial pressure, it is the ppm concentration at 1barA that would have the same partial pressure as that measured)
USB	Universal Serial Bus

2 Installation

2.1 Physical mounting

The sensor is housed in a diecast box fitted with mounting lugs (details in section 6.1). The instrument should be screwed to a suitable surface using the two mounting holes.

2.2 Gas connections

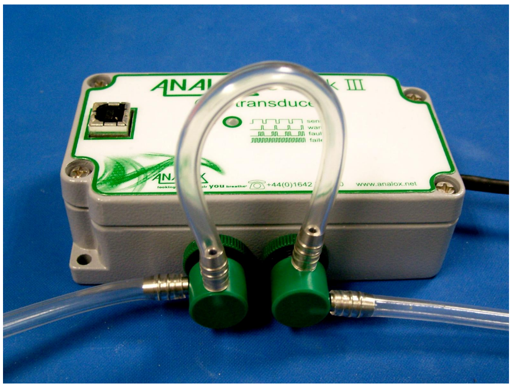
The sensor may either monitor gas in the surrounding atmosphere or a flow adapter can be inserted into the gas port inlet to allow monitoring of pumped sample gas from a remote location.

When used to monitor a pumped sample, care should be taken to ensure that the sample flow rate is within specification and that the exhaust line is not restricted, otherwise gas pressure within the sensor may be increased, resulting in false, elevated CO2 readings.

Single port sensor (% ranges) monitoring local atmosphere

Single port sensor (% ranges) monitoring a remote atmosphere via a sample line.

Dual port sensor (ppm ranges) monitoring local atmosphere



Dual port sensor (ppm ranges) monitoring a remote atmosphere via a sample line

The sensor must be mounted with the gas ports facing downwards so that any accumulation of condensation cannot pool in the gas inlets.

2.3 Oxygen sensor mounting (where applicable)

The 5S3 may be supplied configured to accept an oxygen cell input.

The oxygen sensor should be mounted via a Ø15mm hole in a panel or bracket. It may be mounted in any orientation EXCEPT with the gas port uppermost. This orientation does not damage the sensor but an air bubble may form inside the membrane which effects the cell response, and water may also collect in the inlet which would block it.

2.4 Electrical connections

Electrical connections with the sensor are made via a short screened cable. The cable screen is internally connected to the diecast box and made off into a green/yellow wire.

CORE COLOUR	SIGNAL	DETAILS
Red	+SUPPLY	Power Supply 8-36V DC to Sensor
Blue	-SUPPLY	
Yellow	+OUTPUT	Signal Output from Sensor (0-2V, 4-20mA) **OR:** RS485 communications
Green	-OUTPUT	
Green/Yellow	Earth	Screen

Use of the screen will depend on the particular installation. It is best connected to a clean Earth to form a shield around the sensor. Note that it is not recommended for the screen to be connected to the negative supply line.

It is advised to avoid ground loops. Therefore if the case is adequately earth bonded by the user's fixings, it may not always be desirable to connect the screen to another earth connection. If unsure, it is suggested that the screen wire be connected to earth in the first place, and then if there are problems, an earth loop can be broken by disconnecting one of the connections in the earth arrangement.

2.4.1 Analogue output

The 5S3 can be configured to drive the signal output with either the CO_2 or the O_2 value (when applicable), and the output range may be configured and calibrated using the Analox Sensor Setup Tool.

The standard output range is either 0 – 2V or 4 – 20mA. Maximum load resistance for 4-20mA output is 400Ω. Operation over a reduced range is possible with reduced resolution (eg 0.1-1.0V) and may be configured through the Analox Sensor Setup Tool. Please consult Analox for details.

Note that the sensor output may become slightly negative within the sensor's specifications. For example a 5000ppm sensor is still in spec if it is reading -20ppm on pure helium. In this case the 4-20mA output would produce 3.94mA. Some PLCs indicate a fault under these conditions, if you cannot re-configure the PLC to avoid this then we would recommend configuring the sensor as a 5-20mA output, please contact Analox for details.

2.4.2 RS485 output

By connecting to the appropriate terminals (see section 2.5) RS485 communications are available with the sensor. Using this, data from both the CO_2 and O_2 (where applicable) sensors can be obtained, and calibration commands may be sent to the sensor.

The hardware protocol is 9600 baud, 1 start bit, 2 stop bits, 8 data bits. Two wire communications are utilised with the sensor only transmitting in reply to commands from the master.

Please see Application Note AN-001 for a description of the serial communication protocol, with code and message examples.

2.5 Internal terminal rail

Terminal	Function
1	O_2 mV cell positive input
2	O_2 mV cell negative input
3	Earth (for cable screens)
4	External pressure strain gauge positive supply
5	External pressure strain gauge negative supply
6	External pressure strain gauge positive signal
7	External pressure strain gauge negative signal
8	Earth (for cable screen)
9	Isolated voltage output, positive
10	Isolated voltage output, negative
11	Isolated current output, positive
12	Isolated current output, controlled
13	Isolated current output, negative
14	RS485 A
15	RS485 B
16	RS485 A, use for 120Ω termination resistor or for daisy chaining devices
17	RS485 B, use for 120Ω termination resistor or for daisy chaining devices

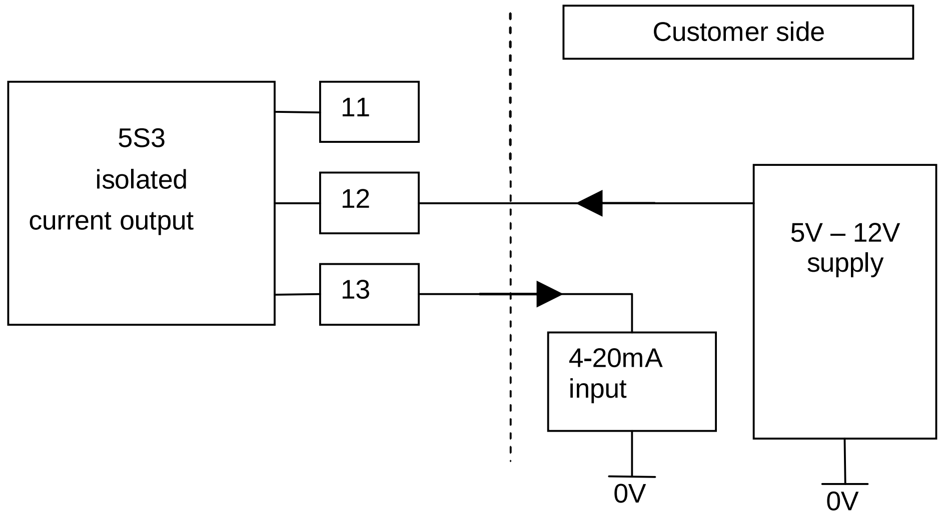
18	5V input
19	0V input
20	Earth
21	8V – 36V input
22	0V input
23	External LED positive
24	External LED negative

2.6 Analogue output configuration

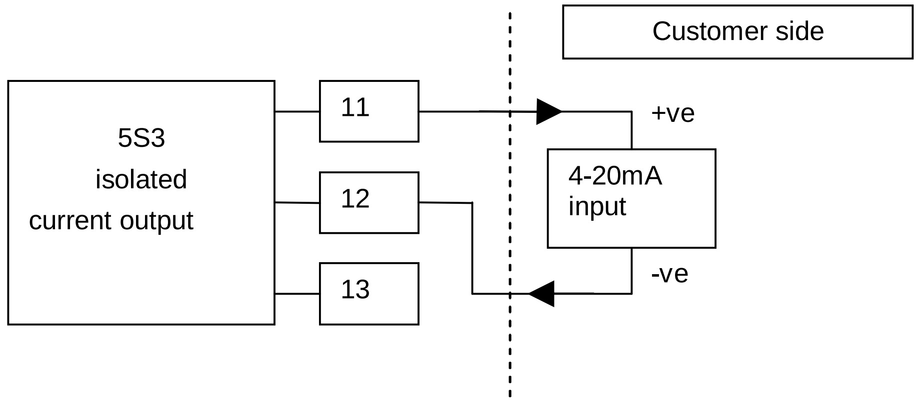
An isolated analogue output is provided. The isolation is rated to 1kV. The output circuitry consists of a voltage output provided by a buffered 12 bit DAC running from a 2.5V supply, and a current output controlled by the DAC. It is possible to simultaneously connect the voltage output and the current output, but they are not isolated from each other and cannot be independently calibrated (because they share a common DAC).

The analogue output has three terminals, it may be used with either an external voltage or it can source the driving current itself. See the following diagrams.

Configuration for customer supplied current:



Configuration for 5S3 supplied current:



2.7 Power sources

The 5S3 has three power inputs:

- An 8V to 36V DC input which is stepped down to 5V. This input is protected against reverse polarity connection.
- A direct 5V DC input, protected against reverse polarity connection.
- The USB input.

The 8V to 36V and 5V inputs are internally connected, so with power fed into the 8V to 36V input, 5V is available on the 5V terminals. **The unit should not be powered simultaneously from these two inputs.**

Internal MOSFET switches prevent power being fed back to the USB power inlet. If the unit is powered from USB and one of the other two inputs, then the power is actually drawn from the other inputs, not the USB input. When the unit is powered from USB, 5V is not available on the 5V terminals.

The 5V input feeds a step-down voltage regulator, the RS485 driver IC and the lamp. Absolute maximum input voltage is 10V, but this voltage is driven back through the RS485 outputs so it may damage the device at the other end of the RS485 bus.

2.8 USB Connection

The USB connector is intended to be used for factory setup and diagnostics. It may also be used for calibration. Please contact Analox for details.

2.9 EMC

The 5S3 is compliant to relevant EU EMC standards.

The 5S3 has passed the type 2 (heavy industrial) immunity requirements of EN50270 (Electromagnetic compatibility – Electrical apparatus for the detection and measurement of combustible gases, toxic gases or oxygen). Maximum deviation under 10V/m radiated immunity testing was 5% of sensor range.

The 5S3 has passed the type 1 (light industrial) emissions requirements of EN61000-6-3 (Emission standard for residential, commercial and light-industrial environments).

3 Operation

During operation the unit continuously runs various self checks. If a fault is detected then the output is driven over-range (to a nominal 20.5mA for current output and 2.5V for voltage output) and the flash pattern of the green LED changes to a double flash. If the sensor suffers a software failure then the flash pattern changes to a very rapid flash and, again, the output is driven over-range.

After switch on, the sensor takes about thirty seconds to warm up. During this time the LED will provide very brief flashes, the analogue output is driven over-range and the "Warmup" flag is set. After the warm up period completes, the analogue output will be driven to be proportional to the CO_2 concentration, as per the specification. The LED will now flash with a longer on time.

3.1 Status indications

Event	Indicator	Signal Output	Action
Warm Up Period (30s from switch on)	Short flashes (more off than on)	>2V (0-2V) >20mA (4-20mA)	None
Normal Operation	Long flashes (more on than off)	0-2V or 4-20mA proportional to CO2 concentration	None
Fault	Double flashes	>2V (0-2V) >20mA (4-20mA)	Service required. Try calibrating or return to Analox
Fatal error	Rapid flashing	>2V (0-2V) >20mA (4-20mA)	Power cycle the sensor, if fault persists return to Analox

4 Specifications

Parameter	Comments	Min	Typ	Max	Units
POWER REQUIREMENTS					
Voltage (8 to 36V input)		8.0		36.0	V
Voltage (5V input)[3]		4.5		5.5	V
Power supply ripple				100	mV
Averaged current	Peaks at 140mA		70	80	mA
SIGNALS					
RS485 transmitted signal levels			5.0		V
RS485 inputs		-9		14	V
RS485 ESD tolerance			±16		kV
4-20mA output max load				400	Ω
ENVIRONMENTAL					
Operational temperature range		-5		55	°C
Storage temperature range	Limited by oxygen cell	-10		70	°C
Humidity	Non condensing	0		99	%RH
Pressure range for atmospheric pressure range sensors[1,2]	Reading is pressure compensated	500	1000	1500	mbar
Pressure range for hyperbaric pressure range sensors	Reading is pressure compensated	0.8		10	barA
IP rating			IP22		
GAS SPECIFICATIONS					
CO_2 25000ppmSEV, 1 to 10 barA	See section 4.2				
CO_2 5000ppm atmospheric pressure	See section 4.3				
CO_2 10000ppm atmospheric pressure	See section 4.5				
CO_2 2% atmospheric pressure	See section 4.6				
CO_2 5% atmospheric pressure	See section 4.7				
CO_2 10% atmospheric pressure	See section 4.8				
CO_2 20% atmospheric pressure	See section 4.9				
CO_2 100% atmospheric pressure	See section 4.10				
O_2 2000mbar, 1 to 10 barA	See section 4.11				
O_2 100%, atmospheric pressure	See section 4.12				
Warmup time	From power on		40		s
Flow rate range		0.1		2.0	litres/min

Notes

1) The sensor will not be damaged by use over the pressure range 500 to 1500mbar. See the section on the effect of pressure below.

2) All specifications assume the ambient pressure is 1000mbar (excluding hyperbaric sensors). The sensor actually measures partial pressure of CO_2, not percentage concentration.

3) See section 2.7 for more information

4.1 Explanation of measurement accuracy specifications

4.1.1 CO_2 sensors

The CO_2 sensor actually measures partial pressure, however for sensors used at atmospheric pressure only it is often convenient to talk in terms of ppm or percentages.

The CO_2 sensor specification is expressed as the sum of four error terms:

- A fixed quantity
- A proportion of the sensor's reading
- A fixed quantity per degree C of temperature shift from the temperature of calibration
- A additional proportion of the sensor's reading for hyperbaric use

For atmospheric pressure sensors the following apply:

Sensor range	Basic accuracy	Temperature sensitivity
1000ppm	±25ppm CO_2 ± 1% of reading	±2.5ppm CO_2 / °C
5000ppm	±25ppm CO_2 ± 1% of reading	±2.5ppm CO_2 / °C
10,000ppm (1%)	±50ppm CO_2 ± 1% of reading	±5ppm CO_2 / °C
2%	±0.02% CO_2 ± 2% of reading	±0.002% CO_2 / °C
5%	±0.05% CO_2 ± 2% of reading	±0.005% CO_2 / °C
10%	±0.1% CO_2 ± 2% of reading	±0.01% CO_2 / °C
20%	±0.2% CO_2 ± 2% of reading	±0.02% CO_2 / °C
100%	±1% CO_2 ± 2% of reading	±0.1% CO_2 / °C

For hyperbaric sensors the following apply:

Sensor range	Basic accuracy at atmospheric pressure and constant temperature	Across full pressure range	Temperature sensitivity
25mbar	±0.25mbar CO_2 ± 2% of reading	± 2% of reading	±0.025mbar CO_2 / °C
100mbar	±1mbar CO_2 ± 2% of reading	± 2% of reading	±0.1mbar CO_2 / °C

4.1.2 Oxygen sensors

The O_2 sensor also measures partial pressure but again for sensors used at atmospheric pressure only it is often convenient to talk in terms of percentage.

The O_2 sensor specification is expressed as the sum of three error terms:

- A fixed quantity
- A proportion of the sensor’s reading
- An additional proportion of the sensor’s reading per degree C of temperature shift from the temperature of calibration
- Due to the inherent linearity of the oxygen cell, no additional allowance is needed for hyperbaric use

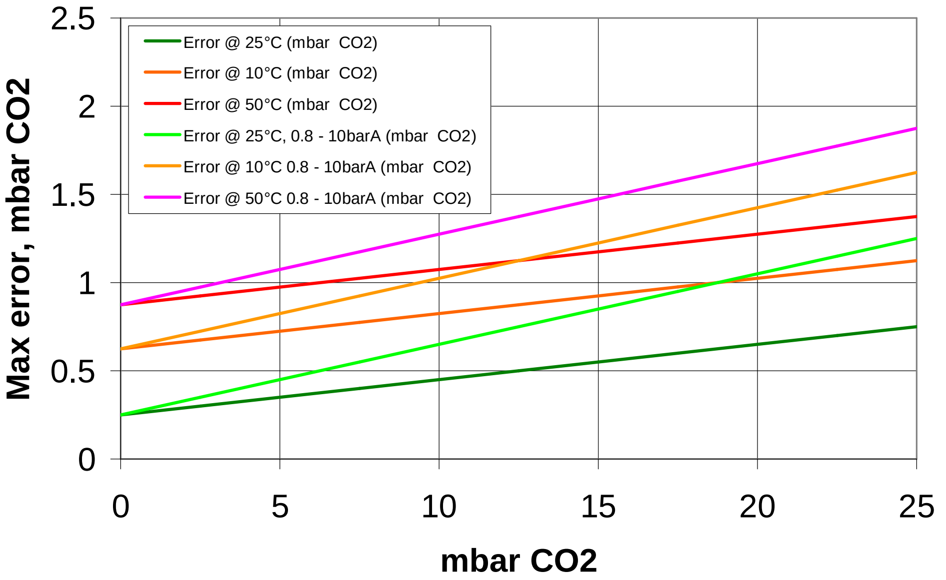
Note that in contrast to the CO_2 sensor, the temperature term is a percentage of reading per °C, not a fixed quantity per °C.

If a product with better temperature stability is required, please refer to our Mini-Electrochemical Cell range of intelligent sensors. They incorporate a more advanced temperature compensation algorithm.

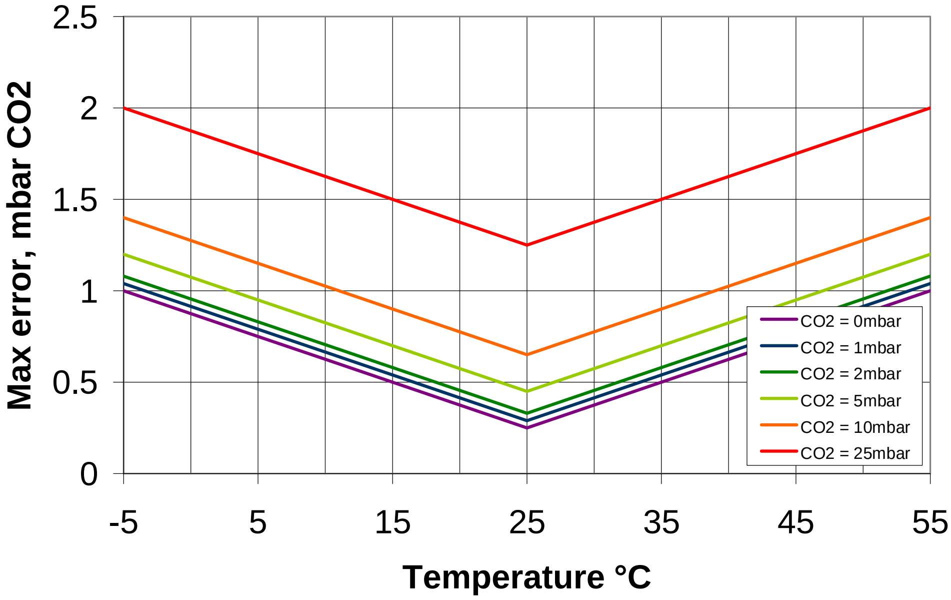
Sensor range	Basic accuracy	Tempco
100%	350ppm ± 1% of reading	±0.2% of reading / °C
2000mbar	2 mbar ± 1% of reading	±0.2% of reading / °C

4.2 25mbar, 0.8 – 10 barA hyperbaric CO_2 sensor

4.2.1 CO_2 error at constant temperature

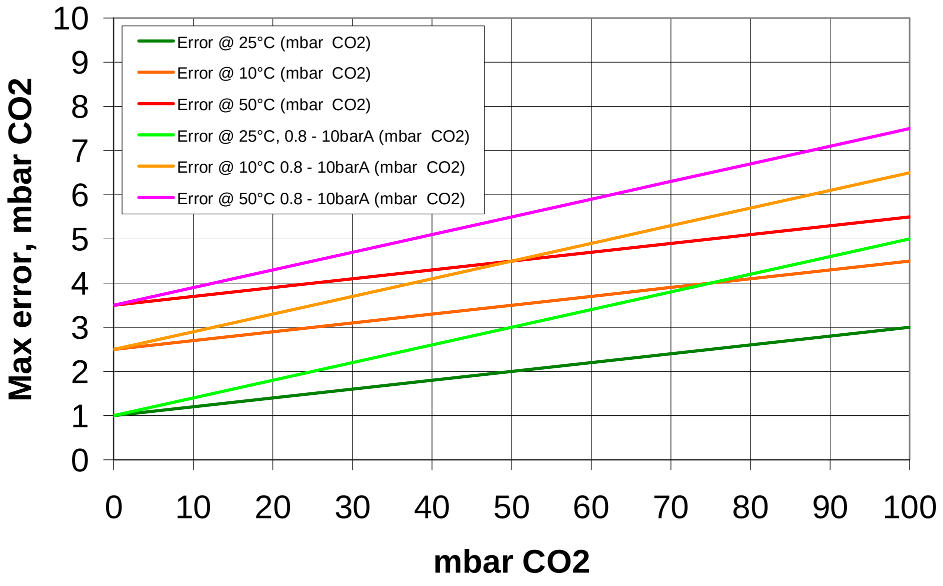


4.2.2 CO_2 error over temperature, pressure range 0.8 – 10barA

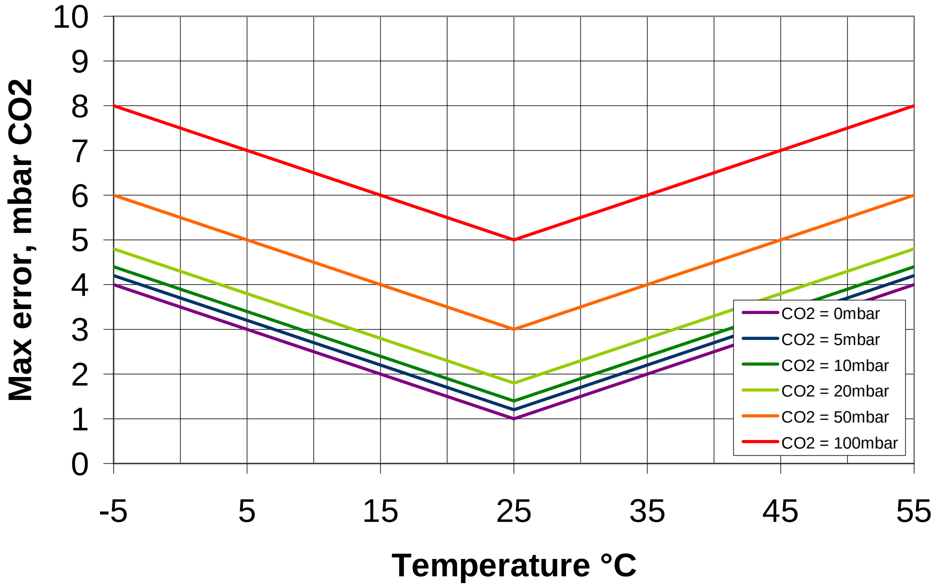


4.3 100mbar, 0.8 – 10 barA hyperbaric CO_2 sensor

4.3.1 CO_2 error at constant temperature

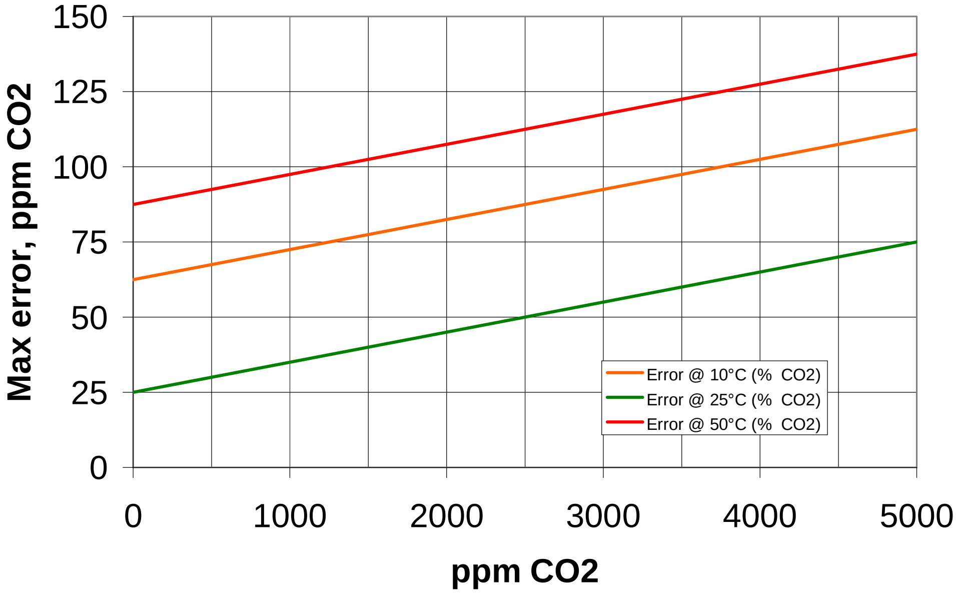


4.3.2 CO_2 error over temperature, pressure range 0.8 – 10bar

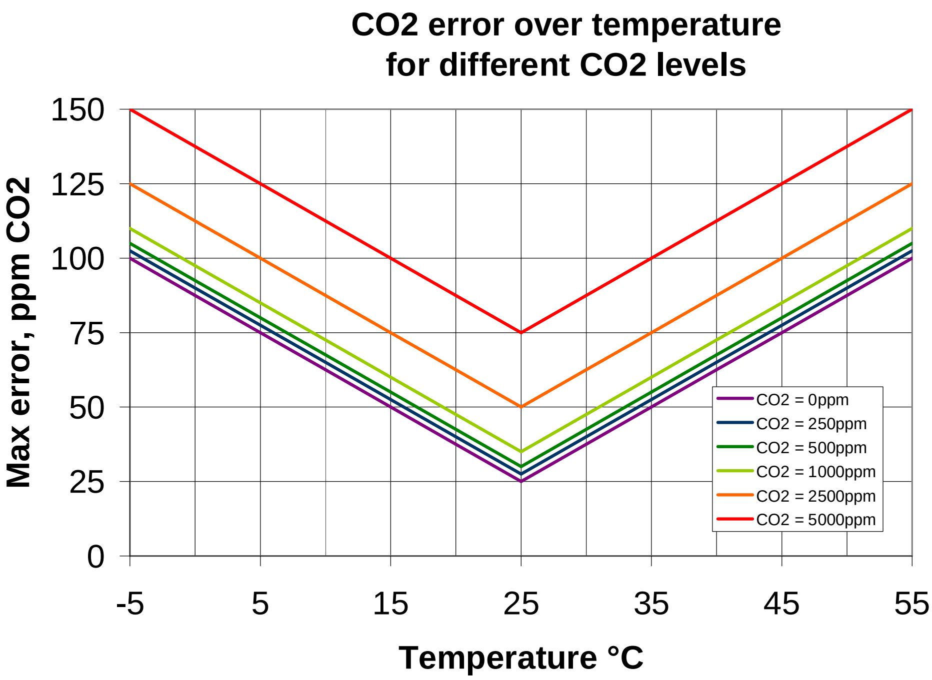


4.4 5000ppm atmospheric pressure CO_2 sensor

4.4.1 CO_2 error at constant temperature assuming calibration at 25°C

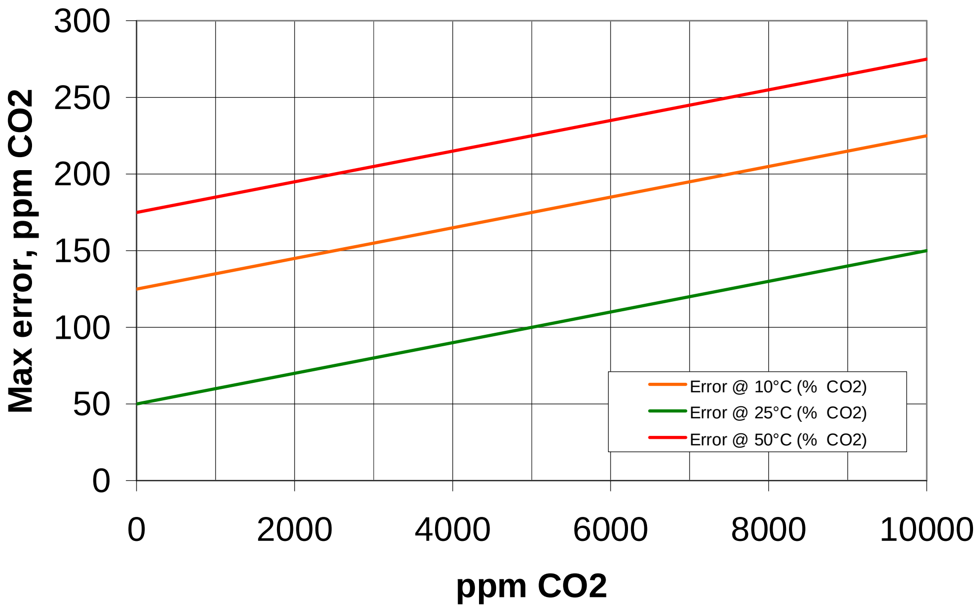


4.4.2 CO_2 error over temperature for different CO_2 levels

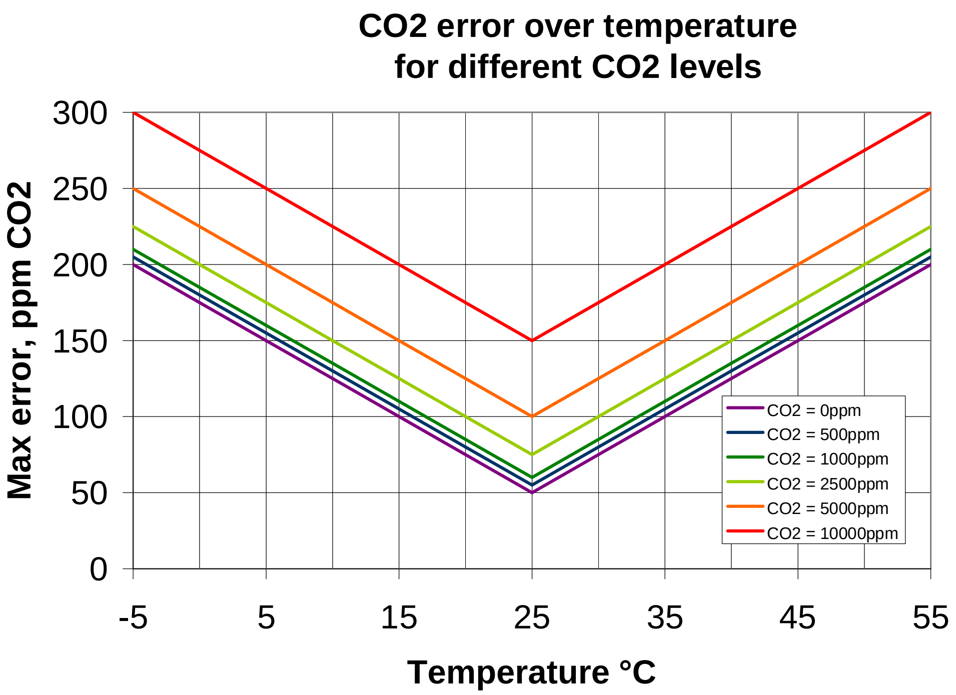


4.5 10,000ppm atmospheric pressure CO_2 sensor

4.5.1 CO_2 error at constant temperature assuming calibration at 25°C

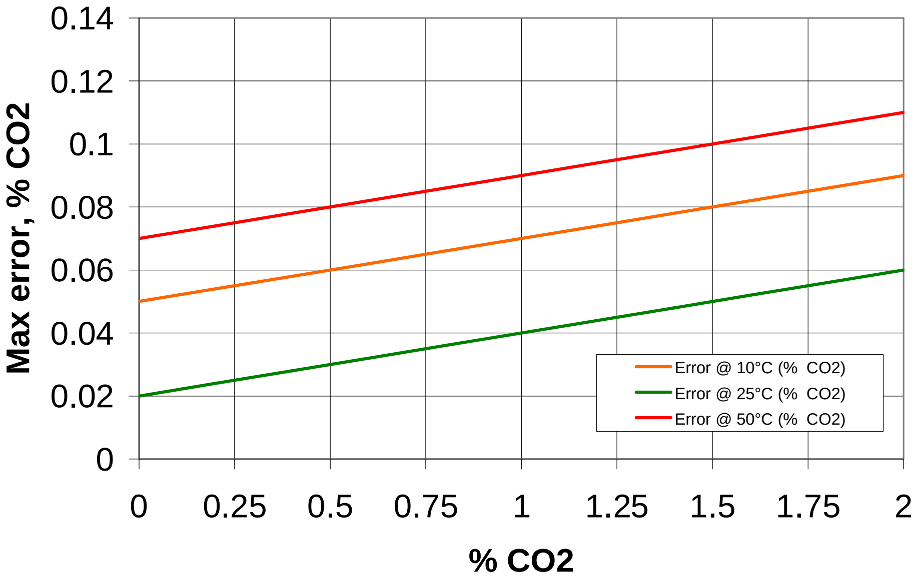


4.5.2 CO_2 error over temperature for different CO_2 levels

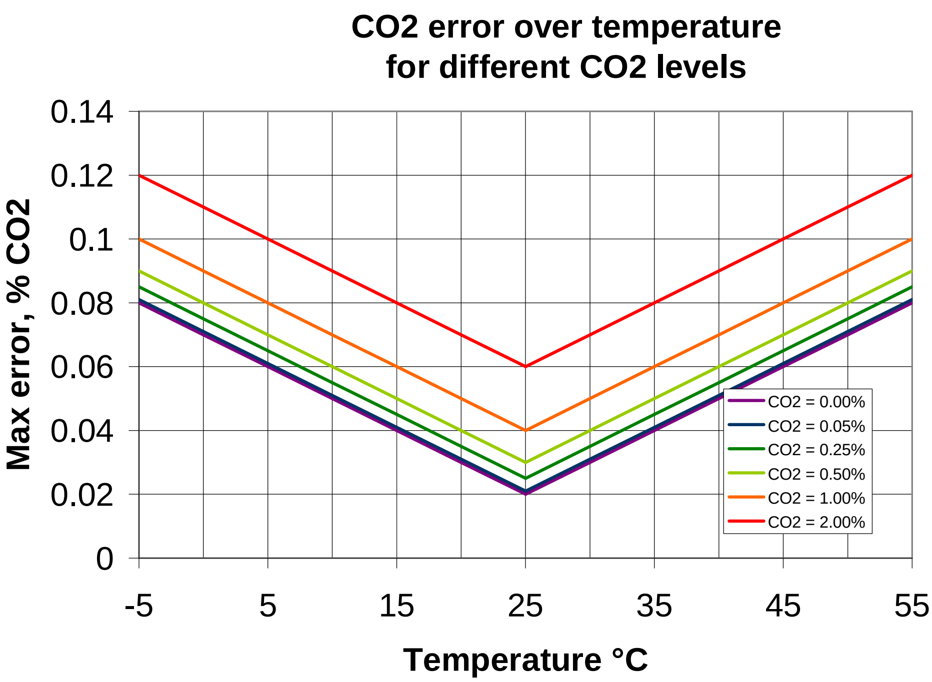


4.6 2% atmospheric pressure CO_2 sensor

4.6.1 CO_2 error at constant temperature assuming calibration at 25°C

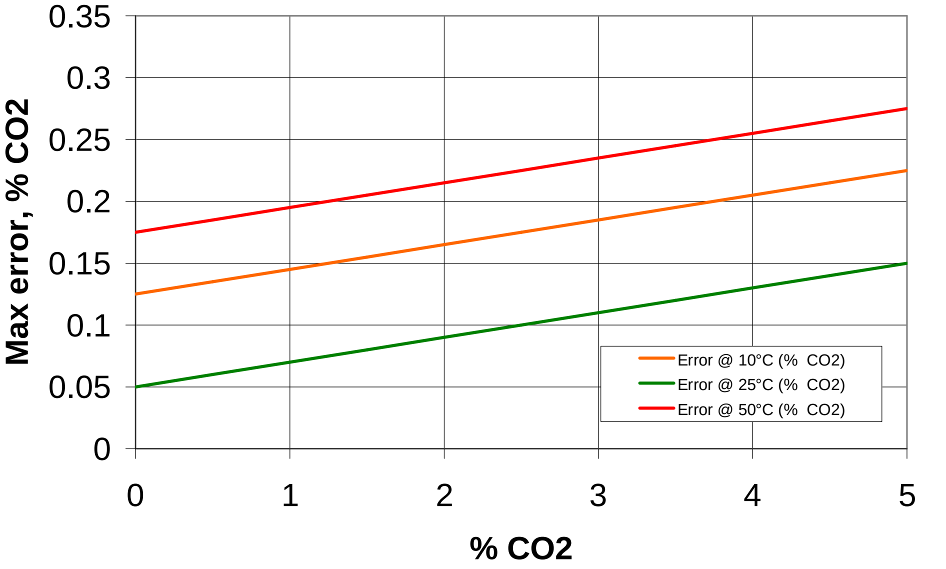


4.6.2 CO_2 error over temperature for different CO_2 levels

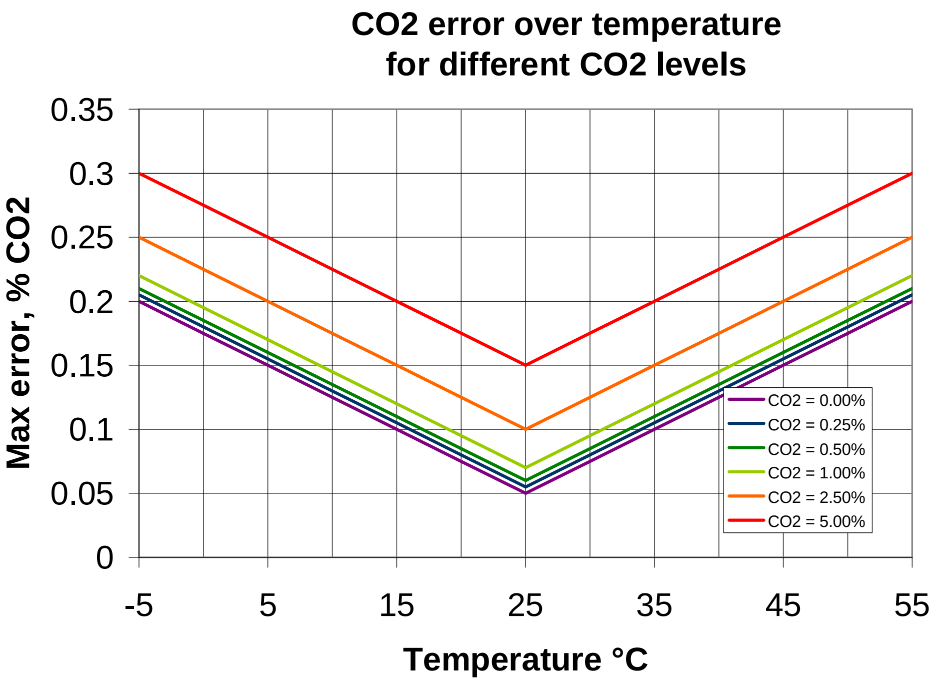


4.7 5% atmospheric pressure CO_2 sensor

4.7.1 CO_2 error at constant temperature assuming calibration at 25°C

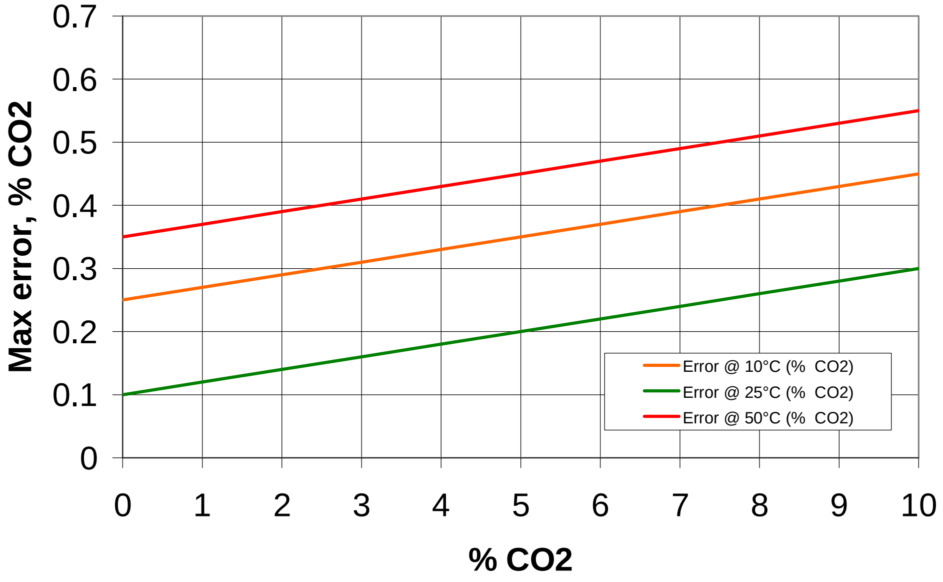


4.7.2 CO_2 error over temperature for different CO_2 levels

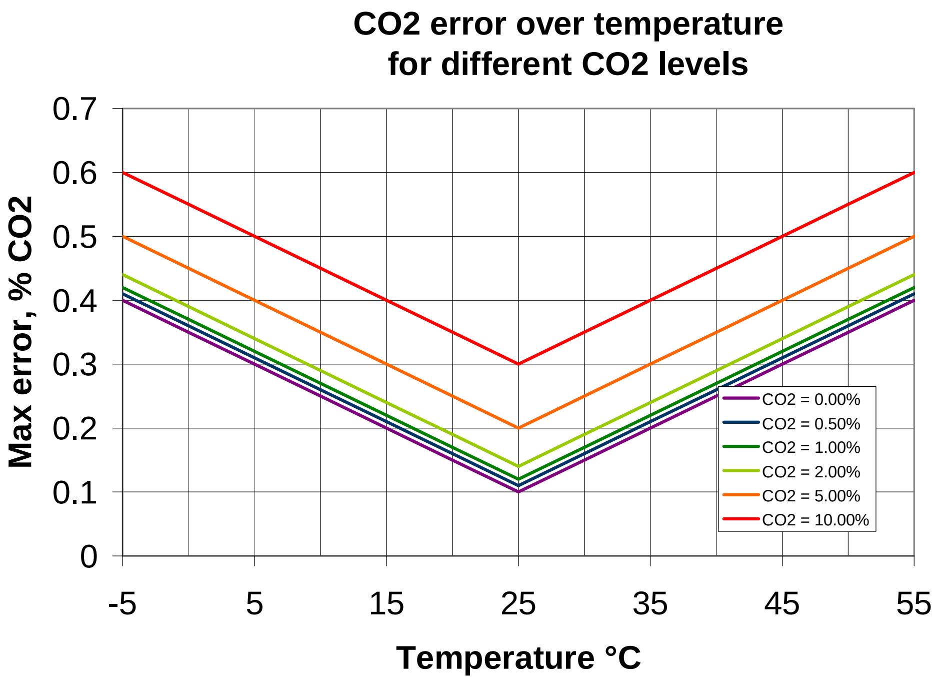


4.8 10% atmospheric pressure CO_2 sensor

4.8.1 CO_2 error at constant temperature assuming calibration at 25°C

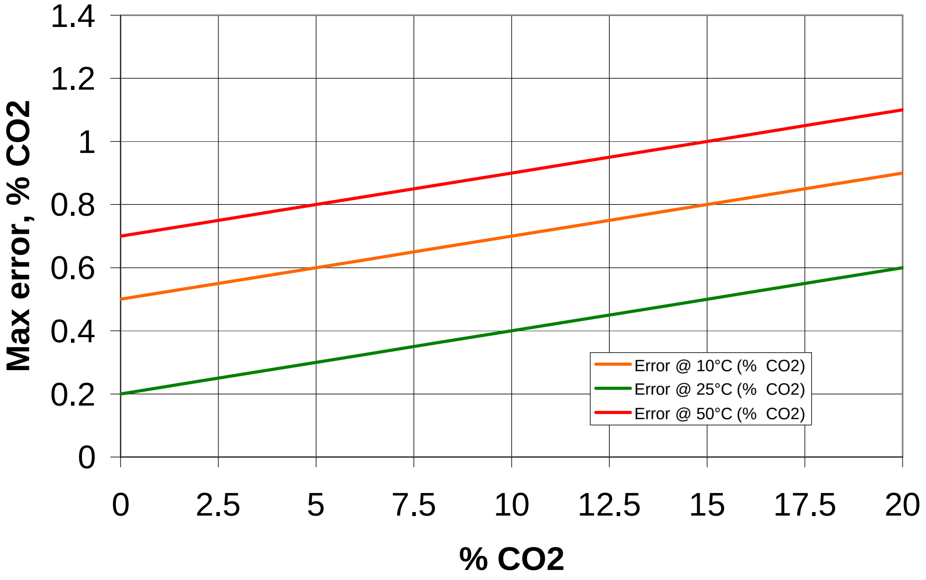


4.8.2 CO_2 error over temperature for different CO_2 levels

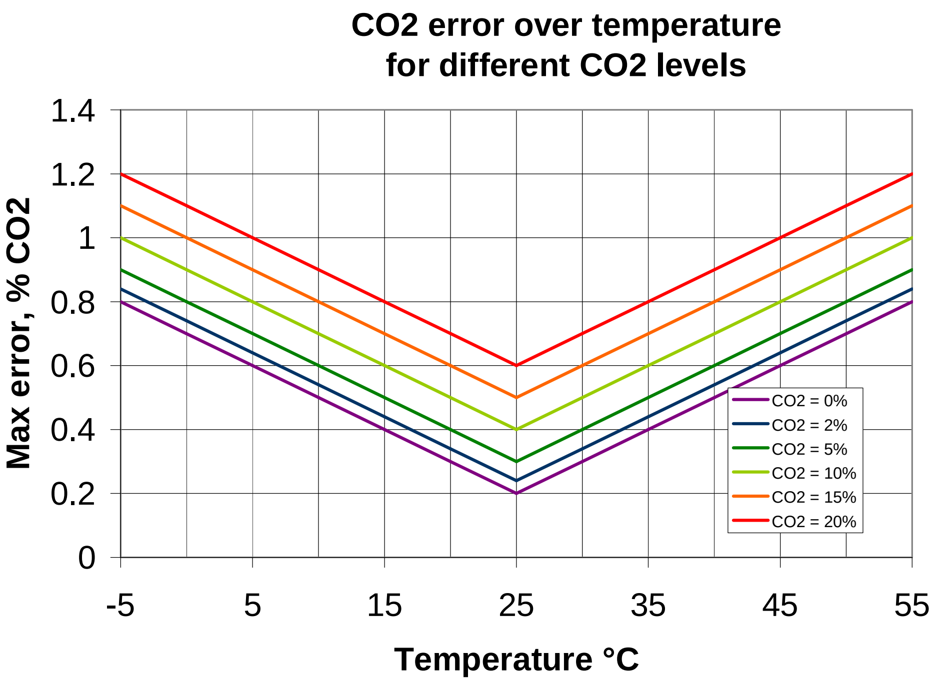


4.9 20% atmospheric pressure CO_2 sensor

4.9.1 CO_2 error at constant temperature assuming calibration at 25°C

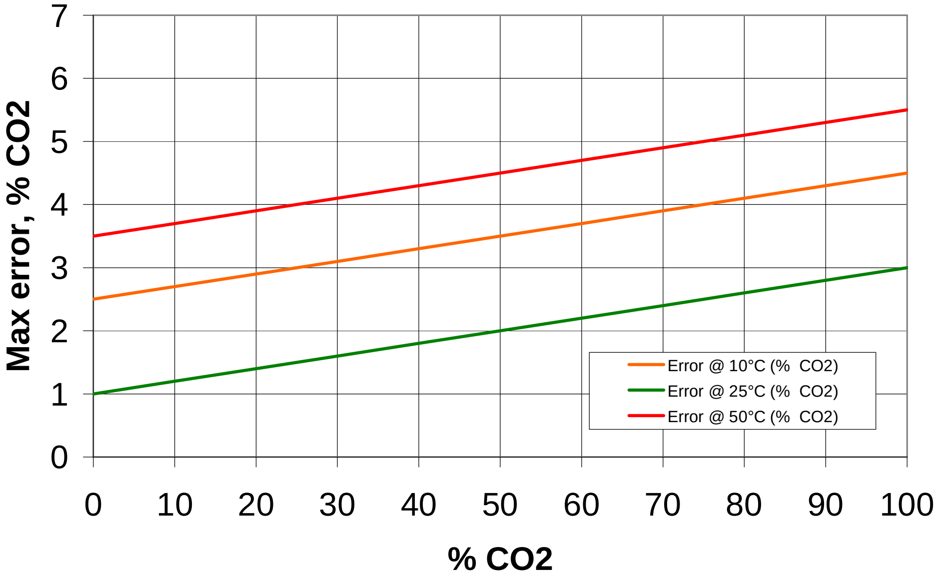


4.9.2 CO_2 error over temperature for different CO_2 levels

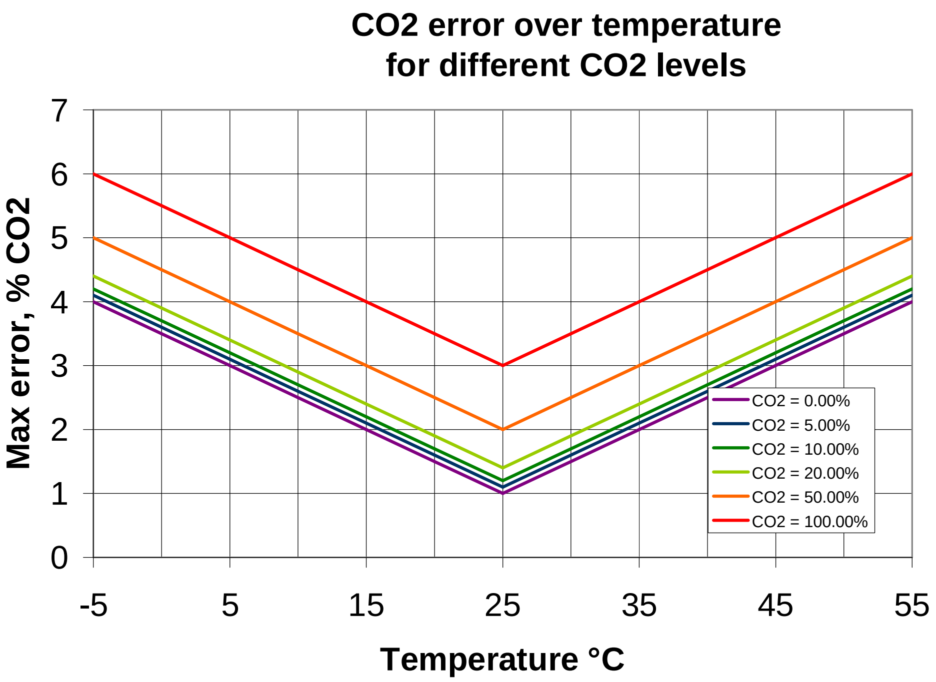


4.10 100% atmospheric pressure CO_2 sensor

4.10.1 CO_2 error at constant temperature assuming calibration at 25°C

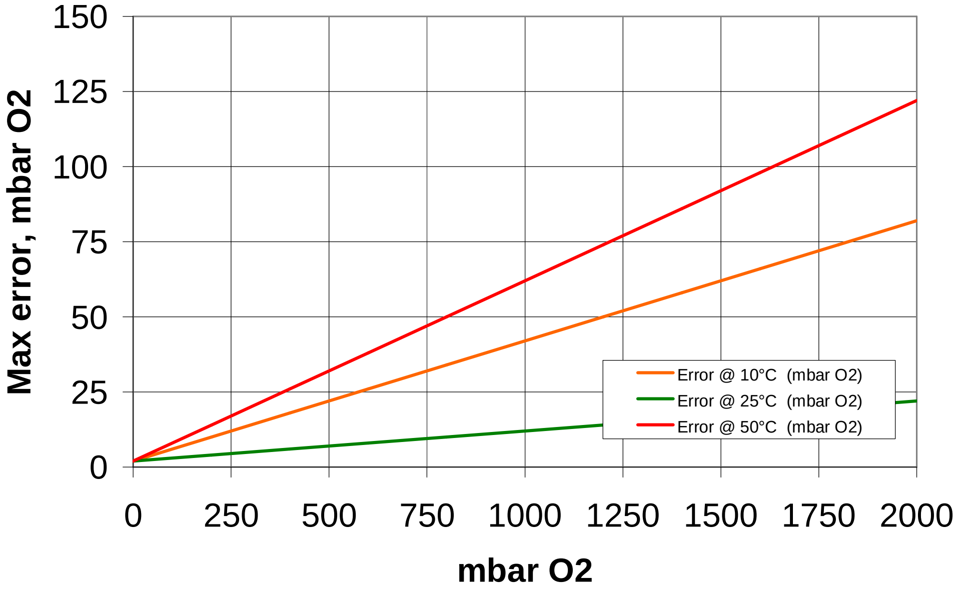


4.10.2 CO_2 error over temperature for different CO_2 levels

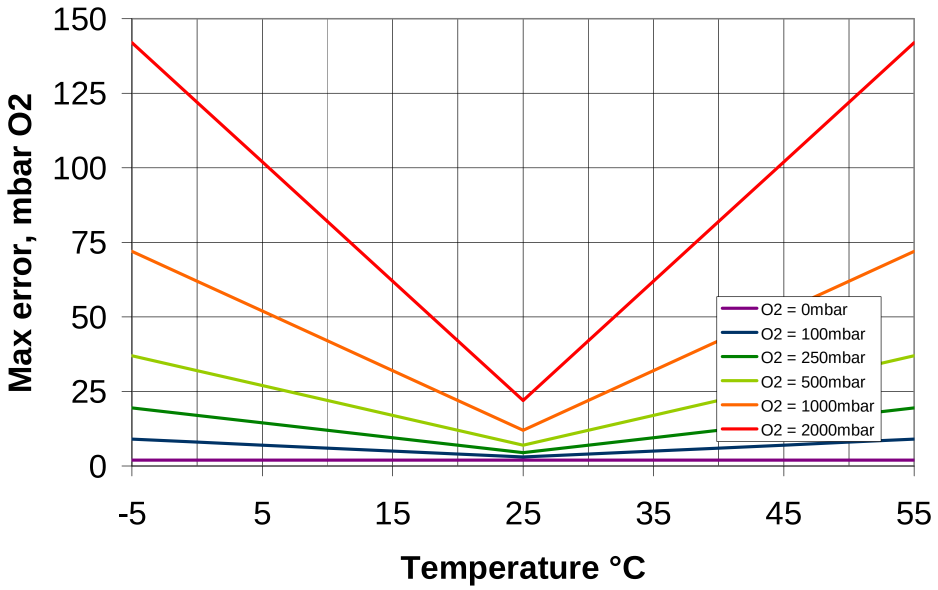


4.11 2000mbar 1 to 10 barA hyperbaric O_2 sensor

4.11.1 O_2 error at constant temperature assuming calibration at 25°C, pressure range 1 to 10 barA



4.11.2 O_2 error over temperature for different O_2 levels, pressure range 1 to 10 barA



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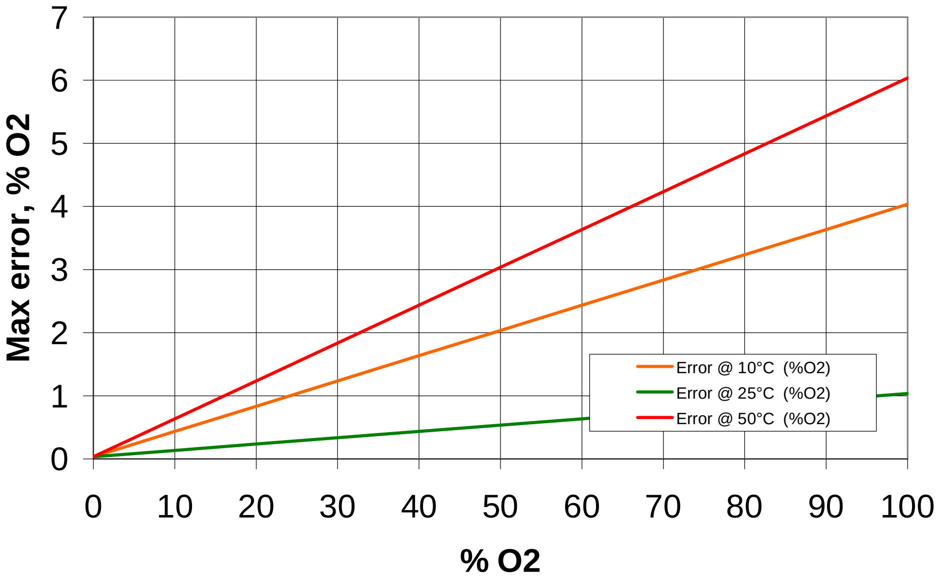
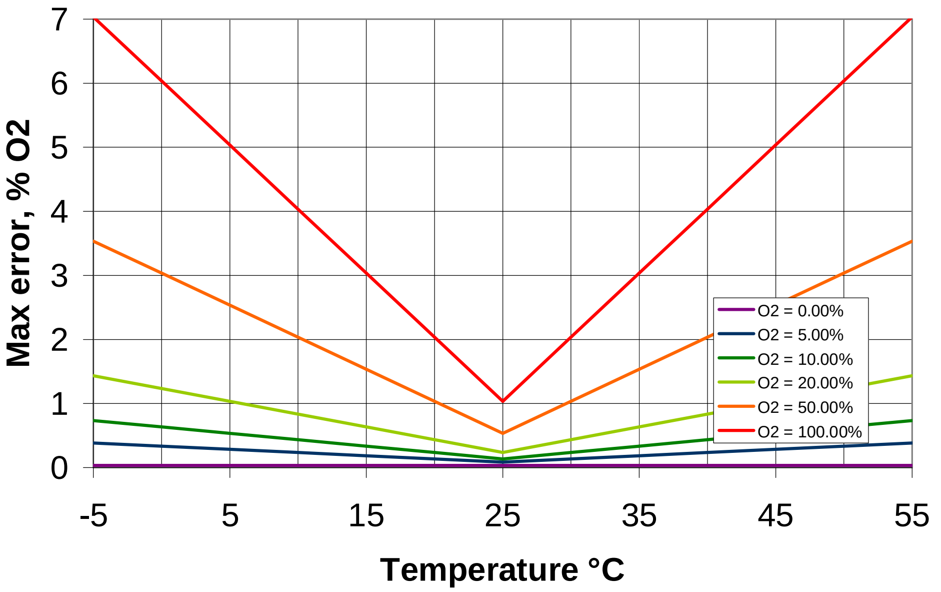
4.12 100% atmospheric pressure alkaline electrolyte O_2 sensor

4.12.1 O_2 error at constant temperature assuming calibration at 25°C



4.12.2 CO_2 error over temperature for different CO_2 levels



4.13 100%, atmospheric pressure acid electrolyte O_2 sensor

Analox are not able to provide our own specifications as yet for this sensor.

This is a special sensor designed for use in areas with CO_2 levels in excess of 1%.

The manufacturer states the following:

- Linearity: within ±2% of full scale
- Temperature compensation: less than ±3% from 15°C to 40°C

5 Spare parts

5.1 Oxygen cell 9212-9H-Sub

Analox part number 9100-9212-9HSUB

Oxygen cells are time degradable items. The sensor will typically last for 3 years when exposed to normal air at normal atmospheric pressure. Regular use in either high temperature environments or in situations using partial pressures of oxygen greater than 209 mbar ppO_2 will cause the sensor to deteriorate more rapidly, and hence shorten its life. For instance, exposure to pure oxygen at standard atmospheric pressure would effectively consume the oxygen sensor approximately five times faster than normal. If maintained in this atmosphere continuously, the sensor would need replacing typically every 6 months. However such exposure would represent fairly severe circumstances, and is not considered likely.

Most commercial diving and military customers tend to replace the sensor at 12, 18 or 24 months, depending on their mode of usage, typical temperatures and typical oxygen partial pressure in the application.

5.2 Oxygen cell, acid electrolyte

Analox part number 9100-1600

This oxygen cell is suitable for measuring oxygen in the presence of significant quantities of CO_2 and other acidic gases.

5.3 Flow adapter

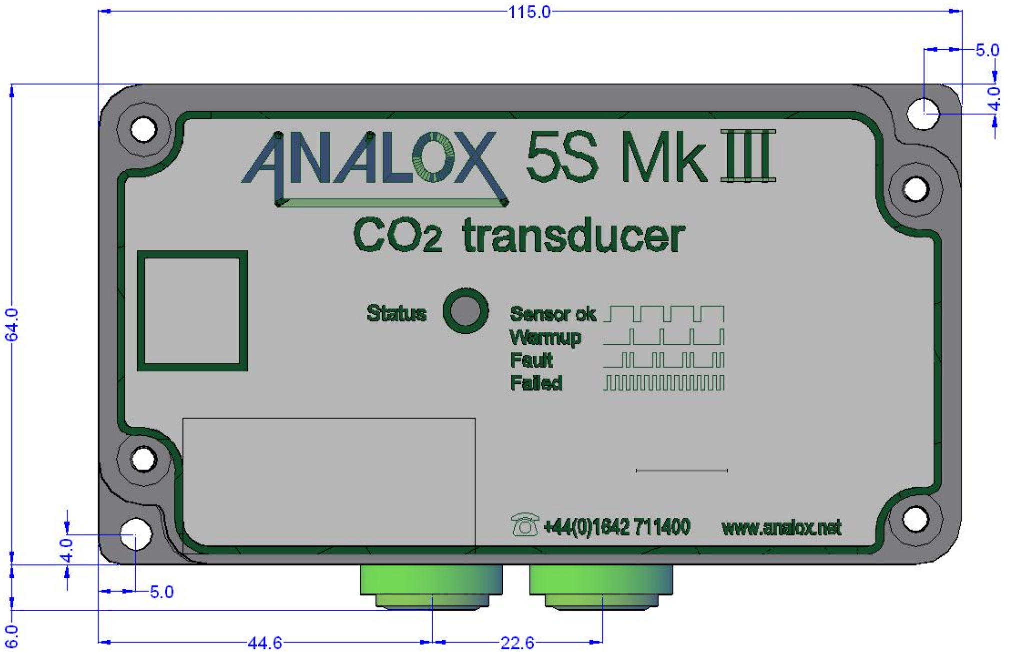
Analox part number 8000-0069A

This is intended for use with tube of 3-4mm internal diameter. Gas can be piped into one port and will then circulate in close proximity to the sensor's hydrophobic membrane before flowing out of the other. Which port is used as inlet and which as outlet is not important.

6 Appendices

6.1 Dimensions & mounting information

6.1.1 Dual port CO_2 instruments (ppm ranges)



6.1.2 Single port CO_2 only instruments (% ranges)