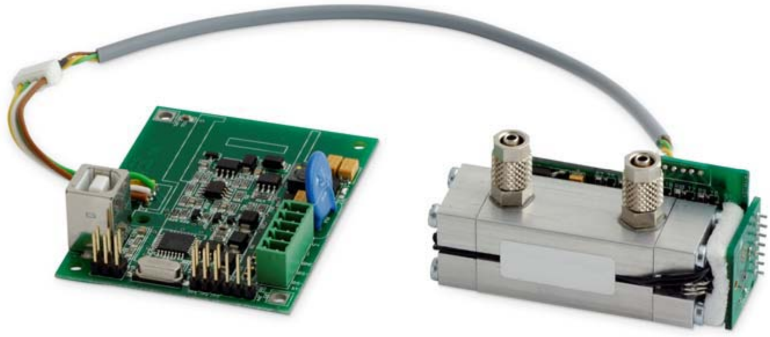
smart*MODUL*^*PREMIUM*

User Manual



Content

1. General

smart*MODUL*^{PREMIUM} combines the advantages of smart*MODUL*^{FLOW} with the circuit board of smart*MODUL*^{CONNECT}.

This combination offers not only a variety of interfaces for data exchange, but also the option of controlled perfusion of the sensors via a gas inlet and outlet.

Based on the physical measurement of infrared absorption, the device is not only highly selective but also provides high levels of accuracy and reliability when measuring gas concentration. Its compact construction and low maintenance needs make it ideal for use even under very difficult conditions.

The smart*MODUL*^{PREMIUM} is ideal for creating a sensor system for measuring explosive or poisonous gases, supplying signals that can be read off either via MODBUS ASCII, as linear analogue current or output voltage.
The rugged housing guarantees that the test gas remains within the measuring cell and provides the system with mechanical protection.

All smart*MODUL*^{PREMIUM} devices can be used with the following outputs:

- 4-20mA (3-wire)
- 0-20mA (3-wire)
- 0-1.0V combined with a 50 Ohm resistance
- 0-2.0 V combined with a 100 Ohm
- RS 485 communication via MODBUS ASCII

The range of different signal outputs makes integration of the device into existing systems remarkably simple, reducing integration and development costs.

Given the wide range of gasses and their concentrations for which the smart*MODUL* has already been developed, smart*MODUL*^{PREMIUM} from smartGAS Mikrosensorik GmbH offers the optimal basis for universal implementation as top quality IR sensory technology.

2. Connections on the smart*MODUL*PREMIUM

smart*MODUL*PREMIUM is supplied with an operational power supply of 12 to 30V DC. Trouble-free functionality is guaranteed within this range.

Despite internal stabilization, voltage supply fluctuation should be limited.

In some cases, such as in plants where heavy loads are switched, the appropriate precautions need to be taken.

The various connections in power supply and output signals are combined in socket **ST1**.

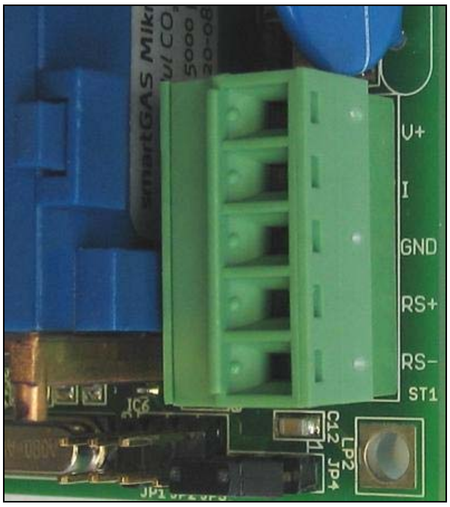


Figure 1. Power supply connections

Connections on **ST1** are designated as follows:

V+	→	power supply connections (12V - 30V DC).
I	→	connection for power output (selectable as 0-20mA or 4-20mA).
GND	→	ground/earth for **V+**, **I and RS485**.
RS+	→	positive signal level for integrated RS485 interface.
RS-	→	negative signal level for integrated RS485 interface.

The measuring cell and interface circuitry are connected by a 30cm data cable.
smart*MODUL*^{PREMIUM} can be supplied with cabling up to a metre length on request.

The connection is made with a four-pole push connector.

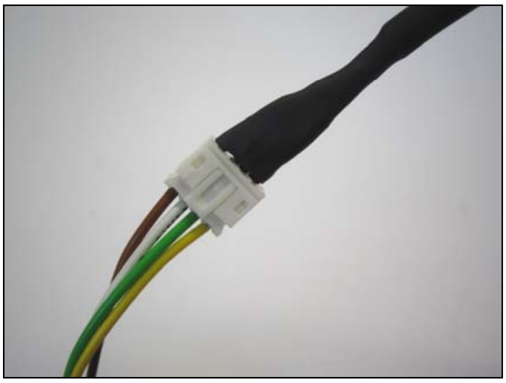


Figure 2. 4-pole connector

3. Connections with smart*MODUL*PREMIUM

smart*MODUL* PREMIUM starts automatically after the start-up phase. (Section.4).

Connections and signal output for the smart*MODUL* PREMIUM are via the **ST1** plug. For operation and use of the current output, the sensor must first be installed and connected.
To avoid faults and possible damage to the device, we recommend adherence to the following sequence of operations:

1. Install smart*MODUL* PREMIUM in the desired application, ensuring sufficient distance from conducting components to avoid short-circuits and possible damage.

2. Remove the green plug from the **ST1** socket. The connections and clamping screws are now easy to reach.

3. Connect the power supply to **V+** and **GND**. Connect the signal cable for current output **I** and **GND**. **GND** is the common ground for the power supply and current signal. Make sure that the sequence of the connections on the plug corresponds to that on the circuit board (make sure the plug is inserted correctly!).

4. re-connect the **ST1** plug.

The smart*MODUL* PREMIUM starts automatically with the start-up phase (see Section 4).

4. smart*MODUL*^PREMIUM^ output signal

4.1 Analogue signal with 0-20mA / 4-20mA or 0-1V (0-2V (resistance)

There are two options for indicating measurement values as current output. Firstly, it is possible to use a range of 0-20mA, combined with a resistance to produce a linear voltage signal. The second option is measurement output with 4-20mA. In this version, it is easier to detect a wire break, loose connection or sensor failure.

The settings for the output signal are described in the following:

a) 0-20mA → Jumper **JP3** is in place (***as supplied***).

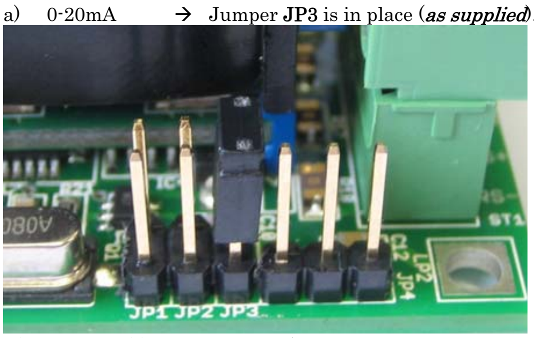


Figure 3. Working range 0-20mA

b) 4-20mA → Jumper **JP3** not in place.

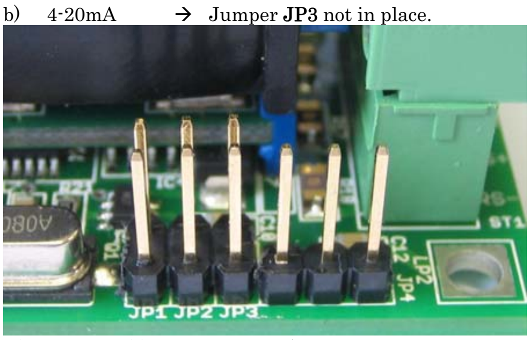


Figure 4. Working range 4-20mA

Select the range of output current for signal transfer you need for your application. Switching between the two ranges is possible once the device is unplugged from the power supply.

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4.2 RS485 Interface

The smart*MODUL PREMIUM* has a RS485 interface (half-duplex). Via this interface the device can communicate via three lines:

- RS- interface's inverted data line
- RS+ interface's non-inverted data line
- GND interface reference potential. This must be used for communication via the interface when the participant does not have the same zero potential (e.g. galvanic separation).

The interface can be accessed via this 5-pole plug connector.

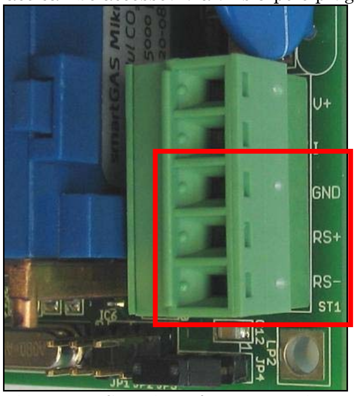
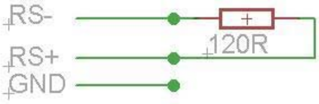


Figure 5. RS485 interface connections

NOTE: *The RS- and RS+ lines should be bridged by at least 30 cm cable with 120 Ω resistance inline.*



RS485 settings

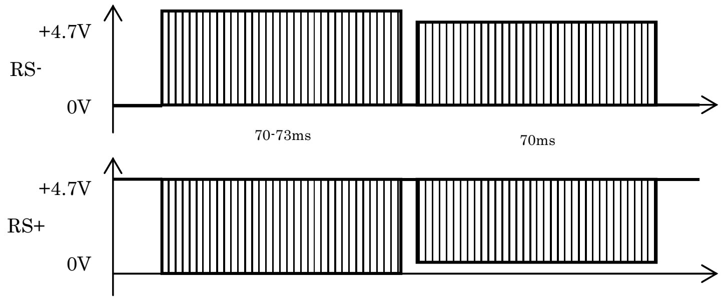
Baud rate:	2400
Data bits:	7
Stop bits:	1
Parity:	Even
Timeout:	1000ms
Retries:	3

TIP: *In some cases it is necessary to increase the Timeout time to 1.5s.*

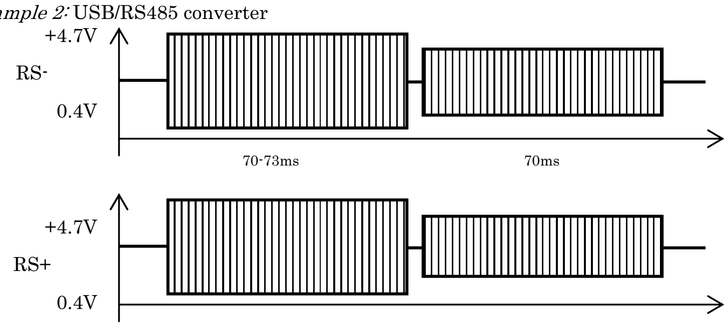
Signal trace

The signal traces at RS485 interfaces can vary greatly. The following are two examples of signals in the data line of the RS485.

Example 1: RS232/RS485 converter



Example 2: USB/RS485 converter



High flexibility of amplitude is available because with RS485 the potential difference of both data lines is evaluated. In the above examples it can be seen that the difference between RS- and RS+ is 0V (inactive) or 2V (active).

A short pause of max 100ms can occur. The module then replies. This depends on how many bytes need to be read off: if only one byte is read then the module reply lasts approx. 70ms. Reading off more bytes correspondingly increases the reply phase.
The amplitude of the data line depends on the RS485 interface used.

4.2.1 smart*MODUL*PREMIUM register assignments

The sequence of registers in the current version is listed below; as they appear in the Host SW. Section 4.2.3 has examples of reading registers.

0xC0	Modbus_address	Current Modbus status of smart*MODUL*PREMIUM. *Standard address: see Page* ***Error! Bookmark not defined.****:*
"Addresses".		
		The addresses can be written and read. After an address has been changed, subsequent communication with the smart*MODUL*PREMIUM is only possible via this address.
0x80 – 0x83	DeviceType	The type of device connected. Read only.
0x86 – 0x89	Serial Nr	Serial number of device connected. Read only.
0x84 – 0x85	SoftwareVersion	Software version of device connected. Read only.
0x05	MOD	Assumed value for internal concentration calculation. Read only.
0x0A	Konzentration	Concentration is stored in this register as a numerical value. Depending on the smart*MODUL*PREMIUM type a factor is still required for the calculation, found in the QS certificate supplied with every smart*MODUL*PREMIUM.
0x03	T_module (0.1x°C)	Internal sensor temperature, as reference point for temperature correction. Read only.
0x45	Alarm_Level	Provides the threshold trigger value for the main gas alarm, referenced to the modulation value displayed for the concentration of real gas. This modulation value is reduced by one, entered in this register and can be freely set by the user.
0x44	Warn_Level	Provides the threshold trigger value for the gas pre-alarm, referenced to the modulation value displayed for the concentration of real gas. This modulation value is reduced by one, entered in this register and can be freely set by the user..

0x09	Status flags	Status flags indicate the states the module can adopt. Read only.

Individual flags, read from right to left, mean:

Flag 0:	Test flag,	value „1" with device test
Flag 1:	Warm-up,	value „1" approx. 10s after start
Flag 2:	Syserr,	value „1" device fault
Flag 3:	Alarm,	value „1" with main gas alarm
Flag 4:	Warn,	value „1" with gas pre-alarm
Flag 5:	Start-up,	value „1" in the start-up phase approx. 90s
Flag 6:	Korr,	value „1" when smart*MODUL*PREMIUM is temperature-compensated.
Flag 7:	mw_ok,	value „1" when das smart*MODUL*PREMIUM has been calibrated.

Flags 6 (Korr) and 7 (mw_ok) are internal flags, set for each process smart*MODUL*PREMIUM during production.
They also have a quality control role and are set to "1" when the smart*MODUL*PREMIUM is temperature compensated and has been calibrated.

4.2.2. Communication with the smart*MODUL*^{PREMIUM} via Modbus Open Protocol

Reading off TTL signals provides access to a small fraction of the information logged by the smart*MODUL*^{PREMIUM}.
Since smart*MODUL*^{PREMIUM} has a large amount of data potentially available it makes sense to use a BUS protocol.
The Modbus Protocol basically works on the master/slave principle. The master (PC or µ controller) sends a request to the slave (smart*MODUL*^{PREMIUM}), which in turn answers. The duration of this phase, until all data is received, depends on how many registers need to be read. As a rule, the smart*MODUL*^{PREMIUM} reacts to the request within 100ms. The character string is sent directly, without reply pause. The slave does not send any data without a request.
The request is always first interpreted after dispatch by CRLF.
WARNING*: Some programmes automatically send the CRLF; with most conventional programmes this needs to be tagged onto the string manually!*

The smart*MODUL*^{PREMIUM} sends no reply if it receives an incomplete request. This is also the case when one or more registers are absent from a register set (section request). An adapted form of the Modbus Protocol is used for smart*MODUL*^{PREMIUM}, differing from the standard version in that one path is used for send and receive. This ASCII protocol uses a serial half-duplex connection.

Datagram structure

The following section describes how a request data string to smart*MODUL*^{PREMIUM} is constructed. The example below shows the current modulation read off from a smart*MODUL*^{PREMIUM} with address 160.

Example string looks as follows:
:A00300050001A6

Start	Address	Ctrl Com.	Data	checksum LRC
1 character	2 characters	2 characters	0-100 * 2 characters	2 characters
:	A0	03	00 05 00 01	A6

Note*: Addresses, control commands and data are prefixed with "0x" and the actual address / commands as "nn". The "0x" merely indicates that the data is hexadecimal, but since the Modbus Protocol ASCII is defined as hexadecimal, this information is superfluous and only the address or command is transferred. The string contains no "0x" and "0x05" becomes "05".*

Start:
As a rule datagrams start with a colon":", irrespective of whether they are requests or replies.

Address
This defines to which device address the string is assigned. As standard, the device address is the last two digits of the *MODUL*PREMIUM serial number as delivered.
Ex.:
Serial number: 22-0800-4***86*** → device address: 86
Serial number: 52-0800-2***28*** → device address: 28

These are added to search for module addresses. Now any register (e.g. concentration) can be requested from all module addresses (1-255) with a timeout of one second. A module with the correct address responds by sending a reply. This reply includes the module address so that at the end of the search cycle it is possible to see by processing the reply which module addresses are currently connected to the bus system.

Control commands
The control commands indicate what needs to be done with the addresses detected. Basically the *MODUL*PREMIUM distinguishes between "Read→0x03" and "Write→0x06".
The command in the example shown here is "Read Register" (0x03→03)

Data
The register number is sent in data as a parameter. In the example here it is "Start Address High (0x00→00) / Low (0x05→05) and Number Register High (0x00→00) / Low (0x01→01)".
The Start Address High" and "Start Address Low" indicate to which register address the control command is directed; in this case, address 0005→0x05 "MOD".
"Number Register High" and "Number Register Low" state how many registers beginning with the start address should be read. Should 10 Registers be read, then 0010 needs to be entered. Registers 05 to 14 are read and transferred. Data is transferred in its hexadecimal form!
The number of bytes doubles after conversion to from ASCII to Hex.

Checksum
The checksum calculates according to a LRC method (Longitudinal Redundancy Check) from all the bytes sent without CR and LF characters.
The bytes are added and the sum subtracted from 0xFF.
1 is added to the result, making the LRC complete.
In the example shown here the value is "A6"

The checksum is always transmitted with the data and recalculated by the recipient. Should a value in the data set become corrupt, then the checksum calculated by the recipient would be different from that sent. The data set in this case would be unusable.

A reply to the string above would look as follows:
:A00302000109

Start	Address	Crtl. Com	No. of bytes transferred	Data	Checksum LRC
1 character	2 characters	2 characters	2 characters	0-100 * 2 characters	2 characters
:	A0	03	02	00 01	09

The following is an example of a checksum calculation.

(Command: Read register 5 only→ Modulation MOD):

Data[0]:=':'; Data[1]:='A'; Data[2]:='0'; Data[3]:='0'; Data[4]:='3';
Data[5]:='0'; Data[6]:='0'; Data[7]:='0'; Data[8]:='5'; Data[9]:='0';
Data[10]:='0'; Data[11]:='0'; Data[12]:='1'
Length=12;

Note: *LRC and CRLF do not belong to the data. CRLF is not included in the LRC calculation!*

1. Lrc=0; *//(checksum is set to 0)*
   For(i=1;i<Length;i++)

2. Lrc=Lrc+data[i]; *//(All transferred bytes are binary added with overflow (8 Bit). Example: 200+200=400. With 8 only 256→ 144 is written = Lrc.*

(In this example the rest sum is 90.)

3. Lrc=0xFF-Lrc; *//(From 255, subtract sum value (90))*

4. Lrc=Lrc+1; *//(255-90+1=166=A6 in Hex (checksum request)*

Example

String :A00300050001

Converted to ASCII values

A = 65
0 = 48
1 = 49
3 = 51
5 = 53

Calculation: A+0+0+3+0+0+0+5+0+0+0+1
65+48+48+51+48+48+48+53+48+48+48+49=602
602-256=346
346-256=90 (Rest!)

Checksum: 255-90+1=166 = A6 in hex.

After calculation of the checksum the following would be sent:
:A00300050001A6

The reply would yield, for example, the following:

:A00302002008 (checksum 08 from reply data packet)

The structure is as follows:

: Start of the frame
A0 -> Address sender
03 -> Register data
02 -> No. bytes (HEX!)
0020->Register data
08-> checksum reply

4.2.3 Examples of registers read offs

All the following refer to a smart*MODUL*[CONECT] with address 160.

- Read off Device Type register

  Send the following string:

:	A0	03	00 80	00 04	A0
Start	Adr.160	read	Startregister	Register no.	checksum

  Reply:

:	A0	03	08	53	4D	2D	43	4F	32	20	20	64
Start	Adr.160	read	no. bytes	S	M	-	C	O	2			checksum

  Data is transferred as characters and can be converted using an ASCII table.

- Read off Serial No. register

  Send the following string:

:	A0	03	00 86	00 04	9A
Start	Adr.160	read	Start register	Register no.	checksum

  Reply:

:	A0	03	08	32	30	08	00	019A	0000	99
Start	Adr.160	read	no. bytes	2	0	08	00	410		checksum

  The first two bytes are transferred as characters and can be converted using an ASCII table.
  The third and fourth bytes are transferred as hexadecimal values and each yields a two-decimal place number.
  The fifth and sixth bytes are summed as a hexadecimal value and produce a three-decimal place number.

- Read off Status flags register

  Send the following string:

:	A0	03	00 09	00 01	A2
Start	Adr.160	read	Start register	register no.	checksum

  Reply:

:	A0	03	02	00C0	F7
Start	Adr.160	read	no. bytes	11000000	checksum

  The two data bytes are summed and transferred as hexadecimal value. If this value is converted to binary number then the flags raised can be determined.

- Read off Software Version register

  Send the following string:

:	A0	03	00 84	00 02	9E
Start	Adr.160	read	Start register	register no.	checksum

  Reply:

:	A0	03	04	33	2E	33	30	22
Start	Adr.160	read	no. bytes	3	.	3	0	checksum

  The data is transferred as characters and can be converted using an ASCII table.

- Read off Concentration register:
  Send the following string:

:	A0	03	00 0A	00 01	9A
Start	Adr.160	read	Start register	register no.	checksum

Reply:

:	A0	03	02	01C8	EE
Start	Adr.160	read	no.bytes	456	checksum

The two data bytes are summed and transferred as a hexadecimal value. If this value is converted to a decimal number, the concentration can be determined (here - 456ppm).

5 Start-up phase

After power supply and current output have been connected to smart*MODUL*^{PREMIUM} the sensor starts a warm-up phase. This lasts approximately 90 seconds and serves as an internal check of all components and routines.

The following states can occur during the warm-up phase, depending on the operating system chosen:

4-20mA: First approx. **2mA**, then a jump to approx. **4mA**.
After approx. 90 seconds I ≥ 4mA, depending gas concentration present.

0-20mA: First **0mA**. After approx. 90 seconds **I ≥ 0mA** depending on gas concentration present.

When the warm-up phase has finished and all test routines completed trouble-free, smart*MODUL*^{PREMIUM} automatically switches to normal operation and displays gas concentration measured as linear current.

6. Wire break between smart*MODUL*^{PREMIUM} and interface electronics

If the connection between a smart*MODUL*^{PREMIUM} and the interface electronics is interrupted (accidental separation or wire break) the following state is displayed at the current output:

Operating with **4-20mA** → Output current is frozen at **2mA**.
Operating with **0-20mA** → Frozen at the **last delivered** current value.

Depending on operating current and switching values, this state can be used as error recognition. If the fault is rectified, smart*MODUL*^{PREMIUM} automatically re-enters the normal warm-up phase and then switches over to normal operation when complete, as described in Section 5.

NOTE:
*If operation with **0-20mA** has been chosen the **frozen current value is maintained until end of the warm-up phase**.*
Trouble-free wire break recognition is general only possible operating with 4-20mA!

7. Using smart*MODUL*[*PREMIUM*] with voltage output

In some applications it is necessary to convert the smart*MODUL*[*PREMIUM*] output signal into a linear voltage signal so that it can be evaluated.
This is easily achieved by inserting a precision resistance into the voltage output (between **I** and **GND**).
The result drop-off in voltage across the resistance reflects the concentration of the gas measured.

Depending on operating current the following voltages can be set:

4-20mA	→	0.2V – 1.0V	with a 50Ω resistor
	→	0.5V – 2.0V	with a 100Ω resistor
0-20mA	→	0V – 1.0V	with a 50Ω resistor
	→	0V – 2.0V	with a 100Ω resistor

NOTE:
The maximum resistance possible for producing output signals is 125Ω.
Anything larger would give rise to measurement error, or even in some cases, damage to smartMODUL[*PREMIUM*]*. The maximum permitted output voltage is 2.5V and should not be exceeded.*

8. Calibrating smart*MODUL*[PREMIUM]

Many applications require sensor calibration after the first operational run up or at regular intervals thereafter.

There are basically two types of calibration to consider.

1. Zero point calibration

This serves to indicate the normal zero gas concentration to the sensor. It is not necessarily 0% gas; measuring atmospheric CO_2 results in a concentration of 350 ppm – 380 ppm. Therefore the selection of zero gas is extremely important.

2. End point calibration

The end point calibration serves to set the upper measurement value (UMV).
This is the maximum value that can be reliably detected and measured by the sensor. When selecting sensors it is important not to set the UMV too small as this may result in inaccuracy and erroneous measurement.

IMPORTANT: smartMODUL[PREMIUM] must be run for at least 15 minutes before calibration!

8.1. Zero point calibration

1. Perfuse the sensor with zero gas, making sure the measuring cuvette has been fully purged and only zero is present.

2. Place a jumper on positions **1-2** in 1**JP4** and wait approx. 20 seconds. The value of the output current should be either 0mA or 4mA (depending on operating system), or drop to 0V or 0.5V (e.g. with 100Ω). Removing the jumper ends calibration and the new value is saved in the sensor.

WARNING: Only run calibration with zero gas, otherwise subsequent measurements may be faulty.

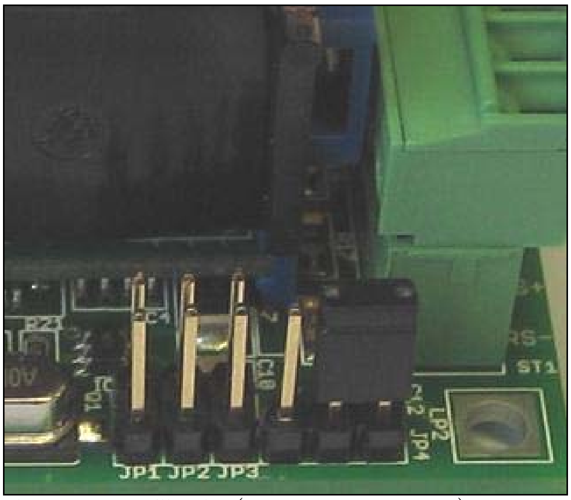


Figure 6. Zero calibration (Jumper on JP4, PIN 1-2)

8.2 End point calibration

1. Flood smart*MODUL*^PREMIUM^ with the gas concentration corresponding to the upper measurement value and make sure no residual gas is present in the cuvette.

   Place a jumper on positions **2-3** on **JP4** and wait approx. 20 seconds. Output should increase to 20mA or 2.0V. Removing the jumper ends calibration and the new value is saved in the sensor.

WARNING: Only run calibration with the appropriate gas concentration for the measurement range given, otherwise subsequent measurements may be faulty.

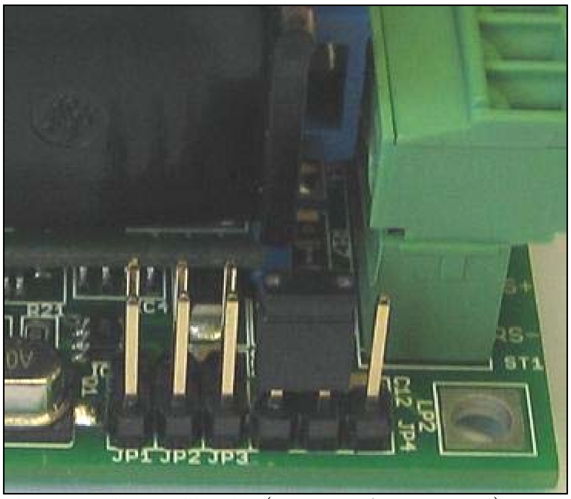


Figure 7. Voltage calibration (Jumper auf JP4, PIN 2-3)

9.Measuring cell with gas line

The smart*MODUL*^{PREMIUM} housing is made of aluminium to protect the sensor from mechanical damage and is with fitted with gas lines to ensure the measuring cell is flooded with the appropriate gas.
The smart*MODUL*^{PREMIUM} housing is made of aluminium to protect the sensor from mechanical damage and is with fitted with a gas line connectors (inlet and outlet) to allow perfusion of the smart*MODUL*^{PREMIUM} (see Figure 8).
Tubing with an internal diameter of 3mm and external diameter of 5mm is needed to connect up to the measurement cell. Ensure that tubing is securely attached to the inlet and outlet connectors.

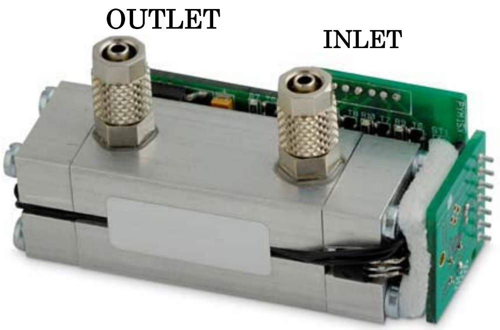


Figure 8: Measurement cell with gas inlet and outlet

Adhere to the directional designation of INLET and OUTLET; switching the direction of gas flow through the cell could lead to erroneous results.

NOTE:
Ensure the correct type of tubing is used. In some applications, corrosive gases occur and could cause problems with the tubing material.
Do not perfuse the smartMODUL^{PREMIUM} *at a gas flow rate of greater than 1l per minute!*

10. General information

Connections not discussed in this document include:

- JP1 ***Must be left free!***
- JP2 Production-relevant
- ST2 USB, production-relevant
- ST4 Keep free!

These connectors are production-relevant and may not under any circumstances be used for normal operation. Misuse or attempts to use these connectors will damage the electronics and void the manufacturer's guarantee!

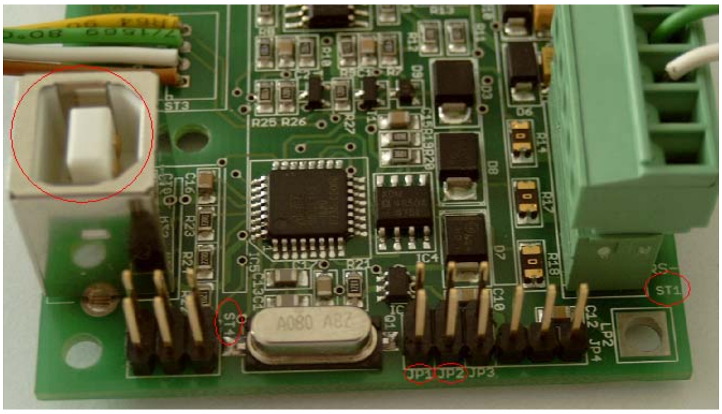


Figure 9. Additional connectors

smart*MODUL*^{PREMIUM} may **only be used with the smart*MODUL* supplied**.
To ensure and maintain the trouble functionality and compliance with the conditions of the manufacturer's guarantee **do not attempt** to exchange or replace the smart*MODUL* supplied with another smart*MODUL*

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Technical data

Product features	
Measurement principle	NDIR (dual beam)
Measurement range	dependent on model (see list of measurable gases)
Cuvette dimensions: H)*	Length (model dependent) x 28 X 42 mm (L x W x
	PCB: 72 x 55 x 21 mm (L x B x H)
Gas line connectors	3mm internal, 5mm external
Technical features	
Response time	< 10 s (at 0.1l/min)*
Accuracy	± 2% upper range value*
Stability	±2% upper range value* over 12 month period
Reproducibility	<2% upper range value*
Linearity error	<1% upper range value*
Error recognition (wire break Modul-Connect):	- output current 2mA (4-20mA) - frozen output current (0-20mA)
Calibration	zero and voltage by jumper
Operating temperature	-10° C - 40° C
Pressure	950 – 1050hPa**
Humidity	0 – 95% rel. humidity
Warm-up time	< 90s (start up time)* 15 minutes (full specification)*
Perfusion rate	0.5 – 1 l/min
Communication	
Analogue output signal	0-20mA linear 4-20 mA linear 0-1 V linear (with 50 Ω) 0-2 V linear (with 100 Ω)
Digital output signal	Modbus ASCII via RS485
Electrical data	
Power supply	12-30Volt DC
Current demand	max. 140mA
Max load	125Ω

* depending on model type

** entering location in register 0x52 the application range in terms of pressure can be increased.

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