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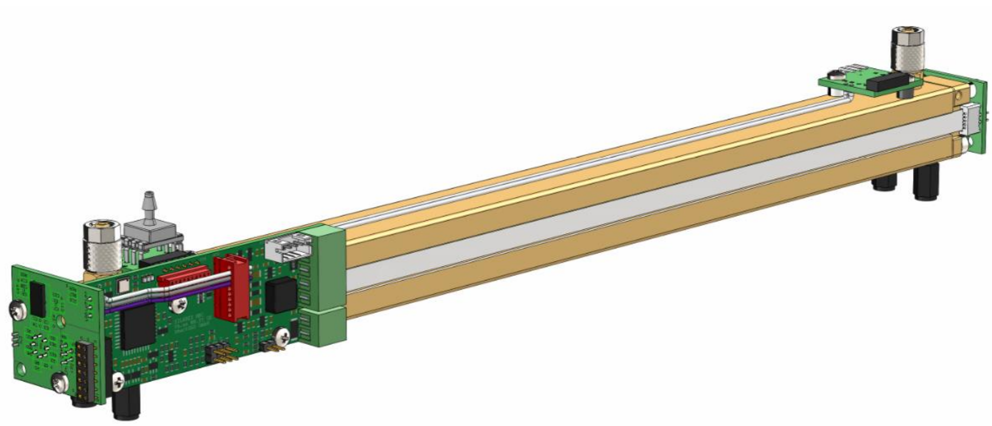
SILAREX

High Performance
Multi-Channel NDIR Gas Sensor

Module and Communication Description for Firmware Version 2.51



Contents

1 General

The SILAREX gas sensor is a “high performance” gas measurement cell with independent measurement capabilities that works with the tried and tested NDIR method. High resolution, measurement accuracy and long-term stability are just some of the features of this newly developed sensor. Thanks to the integrated pressure and temperature compensation as well as its convenient interfaces, the SILAREX sensor is quick and easy to integrate into existing measuring and control systems. Based on the physical measurement method of infrared absorption, SILAREX provides the best conditions for reliable, precise and permanently stable measurements as well as selectivity. Its compact design and the low maintenance effort make it ideal for use in difficult conditions.

1.1 For your safety

Meaning of warning signs

The following warning signs are used in this document to indicate the corresponding warning texts.

CAUTION!

Indicates a potential hazardous situation. If this is not avoided, injuries or damage to the product or environment may occur.
Also warns against improper use.

NOTE

Information on the use of the product

Before connecting and using the SILAREX, ensure that you have read and understood these instructions fully. Please contact our Service department if you have any questions or if anything is unclear. Warning signs indicate important information.
Keep these instructions in a safe place or give them to the device operator for safe keeping if necessary; if the device is sold, the instructions must be transferred to the purchaser. When installing and operating the device, you must follow the statutory requirements and guidelines that relate to this product!

1.2 Intended use

The SILAREX is a gas measurement cell with independent measurement capabilities and is used to determine gas concentrations in accordance with its specifications. It is not suitable for any other measurement or testing purposes and must not be used in any other way.

CAUTION!

The sensor must not be operated in potentially explosive environments or under harsh conditions (e.g. high, condensing humidity, heavy air flow, in aggressive atmospheres or outdoors without a housing).

1.3 Implementation guidelines

- Dry sample gas with less than 5°C dew point – via electric cooler, silica cartridge or similar.
- Reliable particle filtration, e.g. coalescence filters or similar – needs to be checked and serviced frequently
- Stable gas sample flow rate between 0.1 … 1.0 l/min – pump without pressure fluctuation
- Frequent ZERO point check and adjustment – we recommend to use a small standard N2 bottle and a magnetic valve for SW-controlled automatic zero adjustment
- Frequent SPAN adjustment – requires appropriate test gas
- Before applying any form of adjustment, leave the sensor in operation for at least 30 minutes under stable environmental conditions
- Stable sensor temperature insulated from housings or other materials - in the best case the environment or the sensor itself is heated to ~ 40°C

1.4 Loss of warranty / liability / disclaimer

CAUTION!

Opening the sensor as well as manipulating or damaging the device will invalidate the warranty!
The warranty may also be invalidated if aggressive chemicals are used, contamination occurs, liquids penetrate the device or the instructions in this module and communication description are not observed!
smartGAS Mikrosensorik GmbH assumes no liability for consequential loss, property damage or personal injury caused by failing to observe the the module and communication description.

2 Measurement cell with hose connections

The SILAREX measuring cell is made of aluminium and gold-plated. It is equipped with hose connections which ensure that the measurement gas passes through the measurement process. The actual measurement cell is located between the gas inlet and gas outlet

2.1 Hose connection / hose material

Hoses must have an inside diameter of 3 mm and an outside diameter of 5 mm to connect to the measuring cell. Make sure that the hoses are firmly connected to the hose connections.
The connection to the pressure transducer for the (indirect) internal cell pressure measurement is produced at the gas outlet by means of a "T" hose adapter.
Please observe the direction of the gas flow, which is indicated by the labels "INLET" and "OUTLET". Mixing up the gas flow would result in measurements that could significantly deviate from the factory calibration.

Ensure that hoses suitable for measurement are used. Certain applications can generate corrosive gases that could cause problems with the hose material.

2.2 Gas flow

The gas flow should be constant and between 0.1 l/min and 1.0 l/min. The gas must
be dry and free from particles.
Corresponding filters can be purchased from smartGAS.

2.3 Mounting / installation site

Mount the SILAREX using M3 screws with the four polyamide spacer bolts, which are mounted on the underside of the cell. When screwing the sensor onto the mounting plate, make sure that no stress is applied during the mounting.
When using different spacer bolts (than those mounted at the factory) or spacer sleeves, ensure a minimum clearance of 3 mm to the mounting plate.

NOTE

Do not use the other (free) threads in the sensor for mounting purposes.

3 Electrical connection

The SILAREX is connected using the ST1 and ST2 connectors supplied. The supply voltage and communication is connected using ST1.

Connector ST2 is a power output to which external peripheral devices (e.g. a gas pump) of up to 200 mA can be connected.

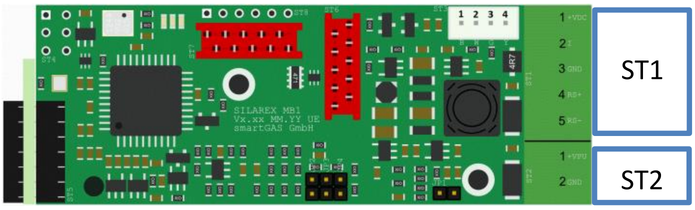


Figure 1: Position of the connectors

Connector ST1

Pin	Assignment
1	+Vcc 12 – 24 V DC
2	NC
3	GND
4	RS485+
5	RS485-

Table 1: ST1 pin assignment

Connector ST2 (power output)

Pin	Assignment
1	5.8 V DC
2	GND
max. 200 mA	

Table 2: ST2 pin assignment

3.1 Current consumption

The following table shows an overview of the current and power consumption. It is strongly recommended to only use adequately dimensioned and voltage-stabilized supply voltages in order to prevent malfunctions due to voltage dips.

Appropriate cable diameters must be used for long supply lines in order to avoid excessive voltage drops over the lines!

Supply voltage	Current consumption
12 V DC	300 mA
24 V DC	250 mA

Table 3: Voltage-dependent power consumption

4 LED status display

Three LEDs (green/yellow/red) are located on the SILAREX circuit board. These show the current device status according to Table 4:

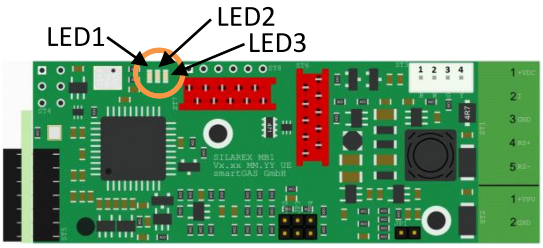


Figure 2: Position of the status LEDs

LD1 (red) O	LD2 (yellow) O	LD3 (green) O	Device status
illuminates	-	-	Device error / contact service
-	flashes	-	- warning, - heating control not at setpoint, - measured value falls below or exceeds the guaranteed range
-	-	flashes	warm-up phase (30 minutes)
-	-	illuminates	Normal operation

Table 4: LED status display

When the system is switched on, it also performs a brief LED check during which the LEDs light up briefly.

5 Pressure compensation (internal cell pressure)

Owing to the physical properties of the gases, their density changes depending on the pressure. This changes, however, depending on the altitude and weather conditions.
For this reason a pressure transducer for measuring the internal cell pressure is already integrated in SILAREX. Hence, the current pressure in the cell is included in the internal calculation of the concentration value.
Automatic pressure compensation in the pressure range of 600 – 1150 mbar takes place. If this range is fallen short of or exceeded, a loss of accuracy is to be expected.

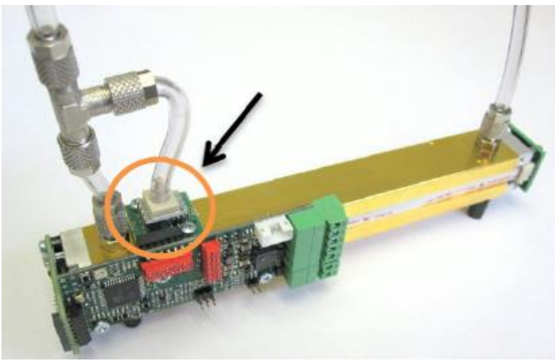


Figure 3: Position of the internal cell pressure sensor

6 Data interfaces

6.1 RS 485 mode

The RS 485 interface is a serial interface that works in 2-conductor mode (half-duplex). Data transmission occurs via symmetrical signals on the RS+ and RS- lines. The reference signal is GND.
The RS485 interface facilitates single master / multiple slave mode, with the sensor acting as the slave. A PC, microcontroller or something similar can be used as the master.
If the subscribers do not have the same zero potential (GND), potential shifts might occur. To prevent these from affecting the terminal devices, the interfaces should be electrically isolated from the rest of the circuit (e.g. by an optocoupler) in this case.

6.2 Signal profiles

The signals are transmitted differentially at the RS485 interface. RS+ routes the signal unchanged, and RS- routes it in its inverted form – see Figure 4. The data signal is evaluated via the difference between the two signals [RS+] - [RS-].

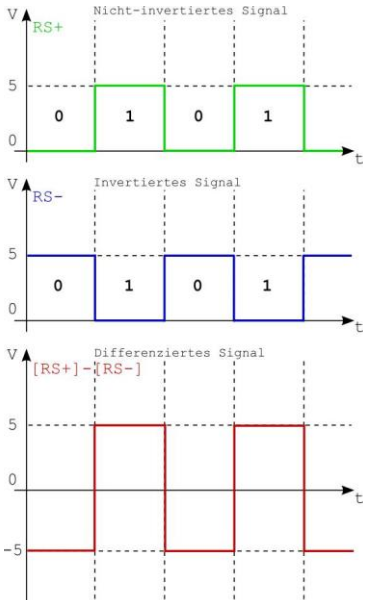


Figure 4: Signal transmission and evaluation on the RS485 data bus

RS485 transmitters provide a voltage difference of at least ± 2 V under load. The voltage difference can become smaller due to potential damping effects. The receivers have a sensitivity of ± 200 mV and can evaluate valid signals up to this value:

[RS+]-[RS-]	**> 200 mV**	**logical "1"**
[RS+]-[RS-]	**< -200 mV**	**logical "0"**
[RS+]-[RS-]	**< 200 mV**	**false interpretation of the data is possible.**

6.3 Data exchange between master and SILAREX (slave)

Figure 5 shows a possible scenario between master and SILAREX (= slave).

The following times refer to Modbus ASCII and a baud rate of 2400 Bd.

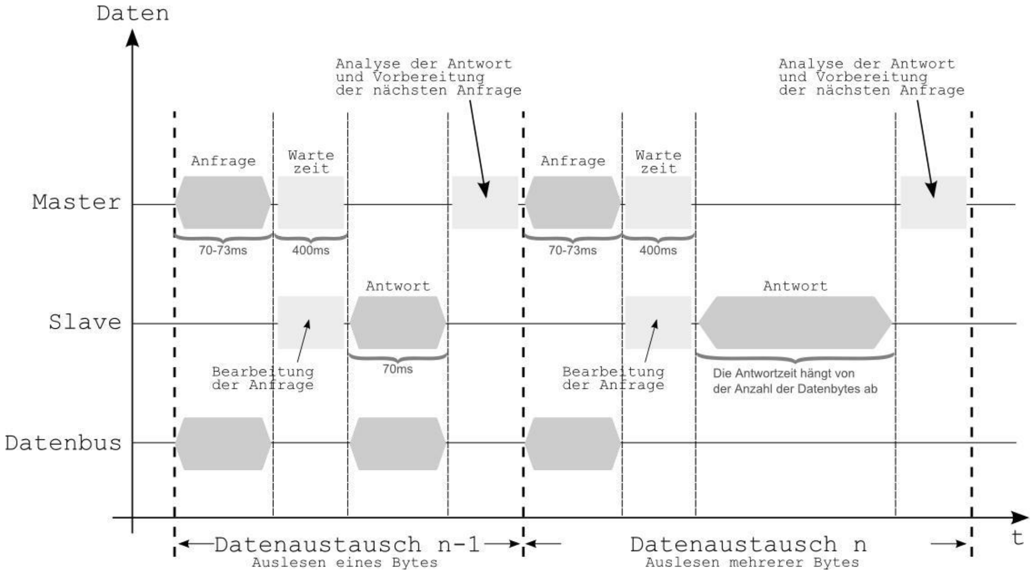


Figure 5: Time diagram – Data exchange between master and SILAREX (slave)

The duration of a query string is 70 – 73 ms. A short pause may then follow (max. 400 ms). The module response then occurs. This depends on the number of bytes being read out. If only one byte is read out, the module response is around 70 ms. When multiple bytes are read out, the response phase is extended accordingly.

Basically, it can be said the SILAREX sensor responds to a query within 400 ms. The character string is then sent immediately without a response pause.

CAUTION!

At higher baud rates (> 2400 Bd), significantly faster response times can be expected.

6.4 RS 485 termination (bus terminating resistor)

From a line length of approx. > 30 m, it is advisable to use a terminating resistor to prevent reflections on the signal lines. The bus terminating resistor (150 ohms) integrated on the SILAREX circuit board can be switched on by connecting jumper JP 1.

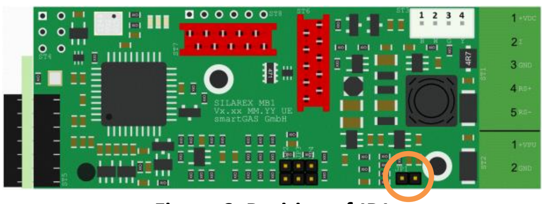


Figure 6: Position of JP1

NOTE

The cable used for wiring should be twisted and shielded (twisted pair cable).

6.5 RS 232 mode via RS 485 interface

If an RS 232 interface is only available for data communication, the RS 485 interface can be configured for the RS 232 mode by an external circuit. RS232 mode requires the sensor to be wired as follows:

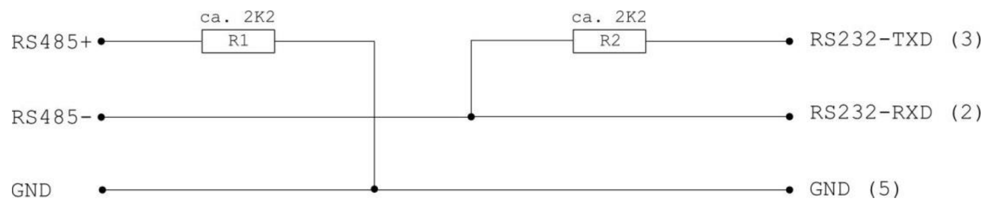


Figure 7: External wiring for RS 232 mode (R1/R2 approx. 2.2 kOhm)

NOTE

Please note the following for the RS 232 mode:

- The transmission rate must not exceed 38400 Bd
- The jumper JP 1 for the termination must not be connected

7 Modbus communication via RS 485 interface

The SILAREX sensor supports the Modbus protocol in ASCII and RTU mode via its RS 485 interface. In ASCII mode, in addition to the standard variant, there is a smartGAS-specific derivative that has a different checksum calculation.

In principle, Modbus communication functions on the basis of a query/response mechanism. The master sends the query to one of possibly several slaves (subscribers). Each connected subscriber therefore receives a subscriber address that is unique in the network. Only the subscriber that has found its address in the query from the master will respond.

The type of query is determined by a control command (function code). This can, for example, be about writing data or reading data to/from the subscriber. Depending on the control command, there is a data portion for both the query and the response.

Each query and each response must be clearly identified by its beginning and by its end. The use of a check field (=check word / CRC) is envisaged in the protocol to enable any possible communication errors to be detected. The Modbus derivatives implement this in different ways.

You can obtain detailed information about the Modbus protocol at www.modbus.org

7.1 Operation with multiple slave subscribers

The RS485 data bus enables up to 32 subscribers to be integrated. The terminating resistors are used at the start and end of the data bus (JP1). The subscribers suspended in-between are guided on the terminated data bus by means of stubs or optimally by means of a “daisy chain” (series connection principle).

At a transmission rate of 2.4 kbps (2400 Bd), the total length of the data bus, including stubs, must be limited to 500 m. Basically, the higher the transmission rate, the smaller the total length of the stubs. The baud rate is determined by the slowest respective subscriber and is the same for all subscribers.

Subscriber position	Designation	Address	Baud rate	Role	Termination (bus terminating resistor)
1	SILAREX sensor	22	2400 Bd	Slave	Yes
2	Computer	----	2400 Bd	Master	No
3	Temperature sensor	11	2400 Bd	Slave	No
4	Pressure sensor	33	2400 Bd	Slave	Yes

Table 5: Example – Data bus with multiple subscribers

As Table 5 shows, the address assigned to the subscribers does not depend on their position in the topology. Since the Modbus protocol is used, the master does not need an address. Only the slaves have to be clearly addressed.

7.2 Automatic detection of baud rate, framing format and Modbus dialect

The SILAREX software is provided with automatic configuration detection. This means that the sensor automatically detects the baud rate, the framing as well as the Modbus dialect used when switching on for the first time in the system.

The framings listed in table 6 and Modbus baud rates harmonise with each another and can be freely combined among each other.

Framing formats and Modbus baud rates	
Framing formats ↓	**Baud rates ↓**
7E1	2400Bd
7E2	4800Bd
7O1	9600Bd
7O2	9200Bd
7N2	38400Bd
8E1	57600Bd
8N1	115200Bd
8N2	
8O1	

Table 6: Freely combinable framing formats / baud rates

NOTE

A framing format of 8 data bits must be used for the communication via Modbus RTU.

7.3 Structure of Modbus data telegrams

As previously mentioned elsewhere, smartGAS Mikrosensorik recommends creating a data telegram with Modbus RTU. It is also possible to create a data telegram with Modbus ASCII, but this is not explained here. The following tables show the basic structure of an RTU data telegram:

Dialect	Start	Slave	Function	Data	CRC	End
Modbus RTU		1 byte e.g.:0x A0	1 byte e.g.:0x03	0 to 1x252 bytes e.g.:0x00,0x05, 0x00,0x02	2 bytes e.g.:0xA4, 0xD3	
Communic ation:	Pause 3.5 characters	0xA0	0x03	0x00,0x05,0x00,0x02	0xA4, 0xD3	Pause 3.5 characters

In RTU mode, each 8-bit byte is transferred unchanged. This necessarily means that UART frames with 8 data bits need to be used in RTU mode. The advantage of RTU mode is the more effective utilisation of the interface: Only around half of the data volume needs to be transmitted compared to the ASCII mode.

7.4 Modbus communication device

Figure Figure 8 shows the state diagram of the transmission and receiving devices in principle, regardless of whether master or slave:

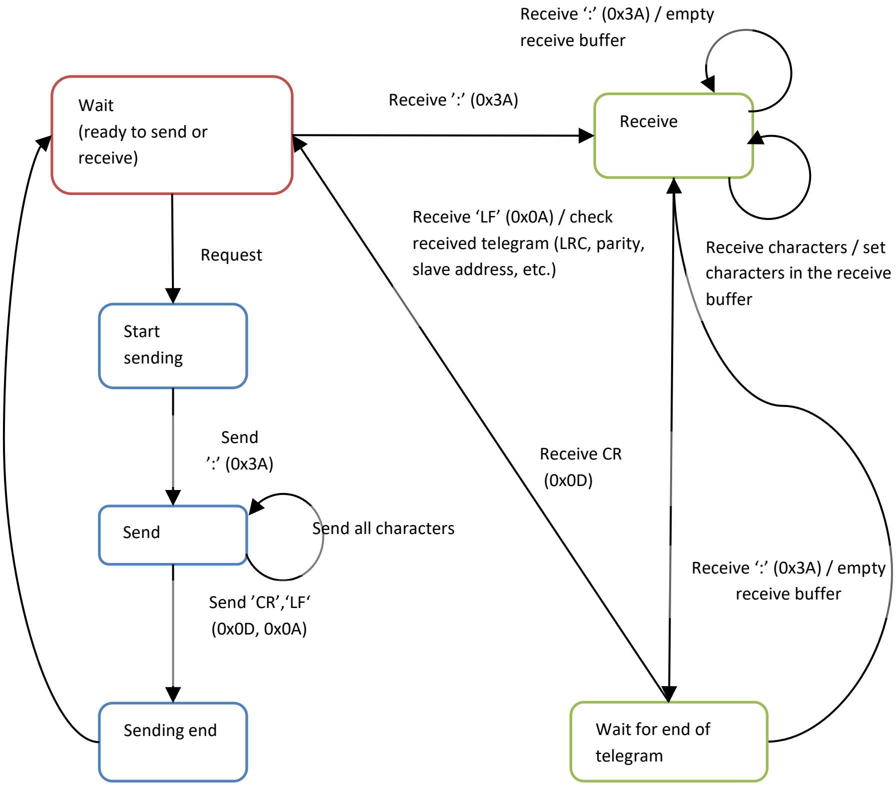


Figure 8: State diagram of a Modbus subscriber (ASCII operating mode)

If an incomplete query is sent to the SILAREX sensor, the sensor does not return a response. The module behaves the same when at least one register in the register area being queried does not exist. Error-free telegrams are processed, others are discarded.

7.5 Modbus address

With the SILAREX sensor, the as-delivered device address (Modbus address) corresponds to the last two numbers of the serial number on the type plate.

NOTE

<u>Example for calculating the Modbus address:</u>

Device address = **#35** decimal → 0x**23** hex

If the serial number ends with "00", the address is always #100 decimal =0x64 hexadecimal.

The address "0" must never be used!

Figure 9 is a flow diagram that shows how unknown Modbus module addresses can be determined. Any register (e.g. serial number) can be queried via all module addresses (1 – 247) with a timeout of one second. If a module is queried with the correct address, it reacts by sending a response. The module address is included in this response. Thus, at the end of the search cycle, module responses can be used to analyse which module addresses are presently connected to the bus system. When the serial numbers are queried, it is then possible to conclude which address is assigned to which module. The permitted address range for SILAREX is between 1 and 247. According to the Modbus specification, the addresses 248 – 255 are reserved. Address 0 stands for broadcast and must not be used!

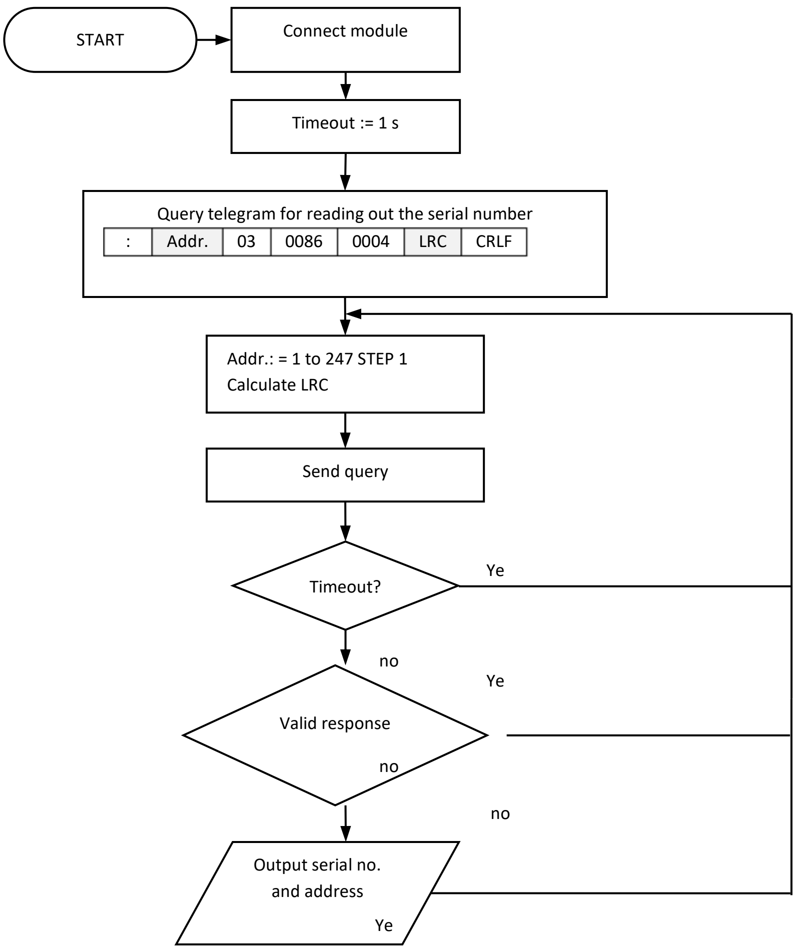


Figure 9: Flow diagram – Determination of module addresses

7.6 Modbus control commands

Two command codes (function codes) are sufficient for communication with the SILAREX sensor. There are the following commands:

- **0x03 – Read Holding Registers (multiple)**
- **0x06 – Write Single Register (single)**

One register is 16 bits wide and thus consists of 2 bytes:

Register		
15	…	0
High Order Byte - Hi		Low Order Byte - Lo

All the SILAREX data that the user can access is shown on registers that are each 16 bits wide.

7.6.1 Control command 0x03 → Read Holding Register

This control command allows you to read values from the SILAREX sensor. Note that only the registers defined in these instructions can be read. Therefore, this must be checked especially when multiple registers are queried.

Query		Response		Meaning of the data (according to ASCII table)
Field	(hex)	Field	(hex)	
Modbus address	0xXX	Modbus address	0xXX	
Function	0x03	Function	0x03	
Start Register Hi	0x00	Byte count	0x08	
Start Register Lo	0x80	Register value Hi (128)	0x53	'S'
Register count Hi	0x00	Register value Lo (128)	0x4D	'X'
Register count Lo	0x04	Register value Hi (129)	0x46	'3'
Checksum Lo	0xXX	Register value Lo (129)	0x43	'0'
Checksum Hi	0xXX	Register value Hi (130)	0x4F	'0'
		Register value Lo (130)	0x32	'0'
		Register value Hi (131)	0x20	'0'
		Register value Lo (131)	0x20	'3'
		Checksum Lo	0xXX	
		Checksum Hi	0xXX	

Example 1: Reading out the 4 registers for "Device Type"

In this example, four registers of the SILAREX sensor were queried starting from register start address 0x0080 (decimal 128). The response consisted of a payload of 8 bytes that can be resolved with the aid of the ASCII table. Example: Response HEX 53 → to ASCII table → letter S

The response is now **"SX300003".** Thus, it is a SILAREX sensor (**SX**) for **(3)** measurement channels and the derivative number (**00003)**.

Query		Response		Meaning of the data
Field	(hex)	Field	(hex)	
Modbus address	0xXX	Modbus address	0xXX	
Function	0x03	Function	0x03	
Start Register Hi	0x00	Byte count	0x02	
Start Register Lo	0x0A	Register value Hi (14)	0x01	456
Register count Hi	0x00	Register value Lo (14)	0xC8	
Register count Lo	0x01	Checksum Lo	0xXX	
Checksum Lo	0xXX	Checksum Hi	0xXX	
Checksum Hi	0xXX			

Example 2: Reading out the "Conc" register (for displaying the gas concentration)

In this example, one register was read starting from the register start address 0x0E (decimal 14). The two data bytes were transmitted combined as a hexadecimal value. If this value (01C8) is converted to a decimal number, the result is a concentration value of 456.

Query		Response		Meaning of the data
Field	(hex)	Field	(hex)	
Modbus address	0xXX	Modbus address	0xXX	
Function	0x03	Function	0x03	
Start Register Hi	0x00	Byte count	0x02	
Start Register Lo	0x4F	Register value Hi (14)	0x00	3, means ppm x 1
Register count Hi	0x00	Register value Lo (14)	0x03	
Register count Lo	0x01	Checksum Lo	0xXX	
Checksum Lo	0xXX	Checksum Hi	0xXX	
Checksum Hi	0xXX			

Example 3: Reading out the "Unit" register

In this example, one register was read starting from the register start address 0x0023 (decimal 35). The two data bytes were transmitted combined as a hexadecimal value. If this value (0x0003) is converted to a decimal number, the result is "3". This stands for the unit ppm with the scaling x 1. Combined with the data from examples 1 and 2, the SILAREX sensor that was read has therefore measured a gas concentration of 456 ppm.

7.6.2 Control command 0x06 → Write Single Register

This command enables a new value to be systematically written to an addressed register. However, it is only possible to write to those registers intended for this purpose.

Query		Response		Meaning of the data
Field	(hex)	Field	(hex)	
Modbus address	0xXX	Modbus address	0xXX	
Function	0x06	Function	0x06	
Start Register Hi	0x00	Start Register Hi	0x00	
Start Register Lo	0xC0	Start Register Lo	0xC0	
Register count Hi	0x00	Register count Hi	0x00	The new address of the module (160)
Register count Lo	0xA0	Register count Lo	0xA0	
Checksum Lo	0xXX	Checksum Lo	0xXX	
Checksum Hi	0xXX	Checksum Hi	0xXX	

Example 4: Writing to the "Modbus_address" register

In this example, a new Modbus address A0 (hex) = 160 dec. was assigned to the SILAREX sensor. Once this communication sequence is complete, the device is only responsive at this new address!

NOTE

The address 0 as well as addresses > 247 must not be assigned!

Query		Response		Meaning of the data
Field	(hex)	Field	(hex)	
Modbus address	0xXX	Modbus address	0xXX	
Function	0x06	Function	0x06	

Start Register Hi	0x00	Start Register Hi	0x00	
Start Register Lo	0x47	Start Register Lo	0x47	
Register count Hi	0x00	Register count Hi	0x00	The zero point has been reset
Register count Lo	0x01	Register count Lo	0x01	
Checksum Lo	0xXX	Checksum Lo	0xXX	
Checksum Hi	0xXX	Checksum Hi	0xXX	

Example 5: Writing to the IR_zero1 register (setting the zero point for measurement channel 1)

In this example, the zero point of the SILAREX sensor has been reset. This was done by writing the value 1 to register 0x0020 (decimal 32). The device subsequently internally calculated and saved the current correction value for the zero point. The value of the correction is then shown when the same register is read out.

NOTE

The zero point must only be set when zero gas has been applied and the concentration value subsequently remains stable.

Query		Response		Meaning of the data
Field	(hex)	Field	(hex)	
Modbus address	0xXX	Modbus address	0xXX	
Function	0x06	Function	0x06	
Start Register Hi	0x00	Start Register Hi	0x00	
Start Register Lo	0x54	Start Register Lo	0x54	
Register count Hi	0x27	Register count Hi	0x27	Correction value has been set to 10000
Register count Lo	0x10	Register count Lo	0x10	
Checksum Lo	0xXX	Checksum Lo	0xXX	
Checksum Hi	0xXX	Checksum Hi	0xXX	

Example 6: Writing to the CONC_gain1 register (end point correction comparison)

In this example, a new end point correction was set for the SILAREX sensor. A value of 2710 (hex) = 10000 (decimal). This is also the delivery condition. A value of 11000 would mean, for example, that the concentration value displayed is 10% higher than internally measured. This register therefore enables deviations of the SILAREX sensor in the concentration display to be corrected.

NOTE

The end point must only be set in this way when a suitable test gas is applied and the concentration value subsequently remains stable!

Before the end point is set, the zero point must have previously been set correctly.

7.7 Calculating the checksum

The calculation of the checksum CRC specifically for the RTU operating mode will now be explained based on an example. How the calculation of the LRC checksums in ASCII standard works is described thoroughly in the documentation of the Modbus standard.

The checksum is calculated via the slave ID, the function and the associated data (start register and register count). As an example, we generate a query for reading out the concentration register from the SILAREX sensor with the address 14 (decimal) = 0E (Hex.)

Query	
Field	(hex)
Modbus address	0x0E
Function	0x03

Start Register Hi	0x00
Start Register Lo	0x0A
Register count Hi	0x00
Register count Lo	0x01
Checksum Lo	0xXX
Checksum Hi	0xXX

Therefore, in hexadecimal format, the resulting byte string is 0x0E, 0x03, 0x00, 0x0A, 0x00, 0x01. The checksum is now created; here is an example code for calculating the CRC checksum:

C# example to calculate modbus RTU checksum:

```
        /// <summary>
        /// Calculates the checksum of an modbus RTU message and adds it to the end
(last 2 bytes).
        /// </summary>
        /// <param name="Databytes"></param>
        /// <returns></returns>
        private void Calculate_CRC(ref byte[] Databytes)
        {
            UInt16 v_CRC = 0xFFFF;

            for (int x = 0; x < Databytes.Length - 2; x++)
            {
                v_CRC ^= (UInt16)Databytes[x];          // XOR byte into least sig.
byte of crc

                for (int y = 8; y != 0; y--)
                {    // Loop over each bit
                    if ((v_CRC & 0x0001) != 0)
                    {      // If the LSB is set
                        v_CRC >>= 1;                    // Shift right and XOR 0xA001
                        v_CRC ^= 0xA001;
                    }
                    else                                // Else LSB is not set
                        v_CRC >>= 1;                    // Just shift right
                }
            }
        }
```

Figure 7: Creating a code example for CRC checksums

After the calculation of the checksum and the end code, the following data string would then be sent: **0xF7A4**

Query	
Field	(hex)
Slave ID	0x0E
Function	0x03
Start Register Hi	0x00
Start Register Lo	0x0A
Register count Hi	0x00
Register count Lo	0x01
Checksum Lo	0xA4
Checksum Hi	0xF7

The checksum is included each time data is sent and is then recalculated by the recipient again. If the data set is corrupted or adulterated, the checksum calculated by the recipient would deviate from that which was sent. The data set would then be unusable.

8 Register overview

Address	Name	R/W	Function / description
0x05	T_int	R/---	Measured value for internal temperature (x0.1°C)
0x08	T_amb	R/---	Measured value for ambient temperature (x0.1°C)
0x09	P_amb	R/---	Measured value for ambient pressure in hPa (=mbar)
0x0A	P_kue	R/---	Measured value for internal cell pressure in hPa (=mbar)
0x0B	SYS_Status	R/---	Status bit bar, see page 211 for details
0x0E	KONZ_1	R/---	Measured value for gas concentration in channel 1 in ppm, vol.% or %LEL (Please note unit code CONC_unit1!)
0x11	KONZ_2	R/---	Measured value for gas concentration in channel 2 in ppm, vol.% or %LEL (Please note unit code CONC_unit2!)
0x14	KONZ_3	R/---	Measured value for gas concentration in channel 3 in ppm, vol.% or %LEL (Please note unit code CONC_unit3!)
0x20	IR_null1	R/W	Setting value for zero adjustment of channel 1
0x22	KONZ_fs1	R/W	Full Scale Channel 1
0x23	KONZ_unit1	R/W	Unit code for gas concentration of channel 1, see page 22 for details
0x24	KONZ_gain1	R/W	Concentration calculation of gain for channel 1
0x3C - 0x3F	gas_name1	R/---	Gas name of channel 1 in ASCII form
0x40	IR_null2	R/W	Setting value for zero adjustment of channel 2
0x42	KONZ_fs2	R/W	Full Scale Channel 2
0x43	KONZ_unit2	R/W	Unit code for gas concentration of channel 2, see page 22 for details
0x44	KONZ_gain2	R/W	Concentration calculation of gain for channel 2
0x5C - 0x5F	gas_name2	R/---	Gas name of channel 2 in ASCII form
0x60	IR_null3	R/W	Setting value for zero adjustment of channel 3
0x62	KONZ_fs3	R/W	Full Scale Channel 3
0x63	KONZ_unit3	R/W	Unit code for gas concentration of channel 3, see page 22 for details
0x64	KONZ_gain3	R/W	Concentration calculation of gain for channel 3
0x7C - 0x7F	gas_name3	R/---	Gas name of channel 3 in ASCII form
0x80 - 0x83	DeviceType	R/---	Device type, max. 8-character text, distributed over 4 registers (e.g.: **SX300003**)
0x84 - 0x85	SoftwareVersion	R/---	Software version, distributed over 2 registers
0x86 - 0x89	SerialNo	R/---	Serial no., a max. 8 characters long, distributed over 4 registers
0x90 - 0x97	ItemNo	R/---	Article number in ASCII format
0x99	Sys_Settings_C	R/W	System settings, explanation see page 21
0xC0	Modbus_Address	R/W	Sensor Modbus address

Table 7: Modbus register table

- **R – Read Holding Registers (multiple)**
- **W – Write Single Register (single)**

NOTE

All other registers not described here must not be changed under any circumstances.

8.1 Meaning of the individual bits in the status bit bar (SYS_Status):

Faults and error messages can be identified with the aid of the SYS_Status register according to the following table.

Bit	Name	Value → Message
00	DET_ERR	1 → IR detector disturbed
01	TMP_ERR	1 → Temperature sensor disturbed
02	PRS_ERR	1 → Internal cell pressure sensor disturbed
03	STR_ERR	1 → IR emitter disturbed
04	EEP_ERR	1 → EEPROM error
05	----	Without function (reserved)
06	----	Without function (reserved)
07	WDG_WRN	1 → After watchdog reset
08	Amb_SEN_ERR	1 → Ambient pressure sensor disturbed
09	WARMUP	1 → Silarex is in the warm-up phase
10	HEATER_NOT_IN_RANGE	1 → Control deviation of the internal cell heating is > 2K (only if heating is active)
11	OUT_OF_LIMIT_UNDERRUN	1 → Measured value falls below or exceeds the guaranteed range (-20% of the measurement range end value)
12	OUT_OF_LIMIT_OVERRUN	1 → Measured value exceeds the guaranteed range (+40% of the measurement range end value)
13	OUT_OF_RANGE	1 → Measured value calculation outside of the displayable number range (-32768…32767) – Measured value output is limited to the displayable range.
15…14	----	Without function (reserved)

Table 8: Allocation of the error messages in the status bit bar SYS_Status

NOTE

The value 0 always stands for the (error-free) normal state.

8.2 Meaning of the individual bits in Sys_Settings_C (customer settings):

The following configuration can be adapted by the customer:

Bit	Name	Value → Message
00	KONZ_LIMITS_OFF	1 → Limitation of the measured value to the specification of the sensor is deactivated. The measured values outside of the guaranteed specification range are not necessarily within the guaranteed accuracy.
02...01	PFILTER_SEL	Setting of the downstream low-pass filter 00 → No downstream low-pass filtering 01 → Average value filter moderate (T90 = 7.2 s) 10 → Average value filter strong (T90 = 60 s) 11 → Adaptive low pass (fast with signal change)
03	PRESS_COMP	1 → Pressure changes in the system are compensated when the measured values are calculated
14…04	----	Without function (reserved)
15	RESTRORE_FACTORY _DEFAULT	1 → Restoration of the factory settings for zero and end point of all measuring channels (CONC_1, CONC_2, CONC_3). The bit is self-resetting.

Table 9: Assignment of the settings in the configuration Sys_Settings_C

8.3 Description of the unit code: CONC_unitX:

For each of the three possible measurement channels there is a unit code (e.g. CONC_unit1 register 0x23 for measurement channel 1), which describes the measuring range and the factor by which the described measured value in register CONC_X must be multiplied.

Table 7 shows the allocation of the value read out in the register **CONC_unitX** to the aforementioned factors

Register value	→	Unit
0	→	Unassigned, for special applications
1	→	ppm x 0.01
2	→	ppm x 0.1
3	→	ppm
4	→	Vol.% x 0.001
5	→	Vol.% x 0.01
6	→	Vol.% x 0.1
7	→	LEL x 0.01%
8	→	LEL x 0.1%

Table 10: Allocation of register value Conc_unitX to the measuring unit / multiplier

NOTE

Partial quantities of < 1 vol.% are usually specified as a ppm value. The following table shows the relationship of vol.% to ppm:

Vol.%	ppm
100	1,000,000
10	100,000
1	10,000
0.1	1000
0.01	100
0.001	10
0.0001	1

Table 11: Relationship of vol.% to ppm

9 Information on start-up and operation

9.1 Self-test / warm-up time

After the SILAREX sensor is switched on, an internal self-test takes place and the yellow LED flashes briefly. Then a function check of the status LEDs takes place. These light up in the following order:

Red → Yellow → Green

The SILAREX sensor is then in the warm-up phase and the green LED flashes. The sensor now supplies measured values, and system errors are evaluated.

NOTE

Correct measurement values are not output during the self-test phase of approx. 3 sec.

Each time after switching on, the sensor requires a warm-up phase of 30 minutes until all temperature-dependent elements have reached their operating point.

Only then are all specifications (measurement accuracy etc. according to data sheet) reached.

For SILAREX sensors with a cell heater, it may take longer to reach the system temperature. This depends on the surrounding environmental conditions. If the control deviation is too great (> ± 2K), the status HEATER_NOT_IN_RANGE is output in the status bar and the yellow LED flashes.

9.2 Setting the zero point

It is advisable to set the zero point

- after reinstallation of the sensor or measuring system
- at regular intervals (must be adapted to the application)
- after repairs / maintenance work on the sensor or measuring system

Before the zero point is adjusted, the sensor must be in operation for at least 30 minutes, a zero gas (e.g. N_2 – 100 vol.%) must flow through the sensor until the indicator for the gas concentration (register Conc_1, 2 or 3) has reached a stable value.

If the aforementioned requirements are met, the value 1 is written in the register IR_zero1 (0x20) and the zero point is thus reset. In the case of multi-channel systems, the process must be repeated for IR_zero2 (0x40) and IR_zero3 (0x60).

9.3 Setting the end point

Setting the end point (also called final value or span calibration) requires the use of a test gas, which should correspond as accurately as possible to the upper range value of the sensor to be calibrated.
The same preconditions apply here as when setting the zero point: the sensor must be in operation for at least 30 minutes and zero gas must flow through it until a stable value has been set in the register Conc_1, 2 or 3.
If all requirements have been met (which has to be tested by multiple querying of the register Conc_1, 2 or 3), the correction value for the respective measurement channel is written in the register Conc_gain 1, 2 or 3.

9.4 Calculating the correction value for the end point

Let us assume that a sensor indicates a concentration of only 978 ppm (called "Conc_Old" here) in channel 1 when a test gas is applied that has the value 1003 ppm (called "Conc_Cal" here).
Reading the Conc_gain1 register yields the value 9985 (called “Gain_Old” here).

The new calculation of the correction value for the Conc_gain1 register then takes place as follows:

Conc_gain1_New = Conc_Cal x Gain_Old / Conc_Old
Conc_gain1_New = 1003 x 9985 / 978 = **10240**

The new value of **10240** is now written in the register Conc_gain1 (0x24) and the process is completed!

NOTE

Setting the end point only makes sense if the zero point has previously been set correctly.

9.5 Restoring the calibration parameters to factory settings

When bit 15 is set in Sys_Settings_C (page 22) the factory setting of the calibration parameters for zero and end point of all measuring channels (CONC_1, CONC_2 and CONC_3) can be restored.

10 Integrated cell heater

The SILAREX sensor is equipped with a cell heater. This stabilises the cell to 42°C. Depending on the ambient conditions, it is possible that the heating output is not sufficient to reach the specified temperature on the sensor. The sensor can then be installed, for example, in a heat-insulating housing. Please contact smartGAS if you have any questions about this.

NOTE

The current temperature on the sensor can be read out via the register and 0x05 (T_int).

11 Mechanical dimensions

(all measurements in mm)

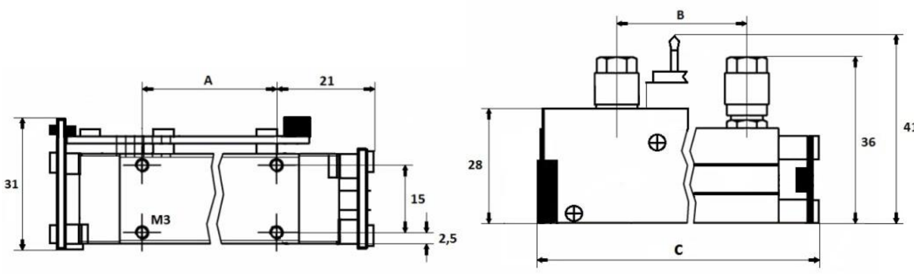


Table of the dimensions (all other dimensions are approximately the same for all device versions)

Cell length →	125 mm	155 mm	305 mm
A →	110	140	290
B →	110	140	290
C →	155	185	335

12 Legal information

The figures and drawings used in this description may differ from the originals; they are provided solely for illustrative purposes.
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