Datasheet – STC31-C

Smart CO$_2$ sensor based on thermal conductivity

Highlights

- Digital and calibrated output of gas concentration and temperature
- Long-term stable measurement

- Low power
- Low-cross-sensitivity to humidity and oxygen concentration changes

The STC31-C sensor is a thermal conductivity gas concentration sensor designed for high-volume applications. The STC31-C utilizes a revolutionary thermal conductivity measurement principle, which results in superior repeatability and long-term stability.

The outstanding performance of these sensors is based on Sensirion's patented CMOSens® sensor technology, which combines the sensor element, signal processing and digital calibration on a small CMOS chip. The well-proven CMOS technology is perfectly suited for high-quality mass production and is the ideal choice for demanding and cost-sensitive OEM applications.

With the introduction of the STC31-C as successor of the STC31, the low-cross-sensitivity measurement mode has been introduced. It provides low-cross-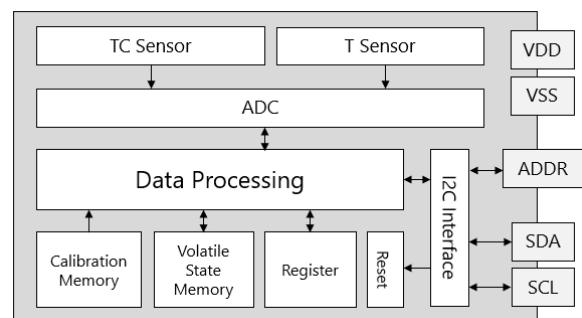sensitivity to humidity and oxygen concentration changes. **The STC31-C is fully backward compatible to the STC31.** See **notice at the end of the document**.

Device Overview

Product	Details
STC31-C	SMD Component on Reel
Evalkit	STC31-C + SHT40 on Flex PCB

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—Thank you!

Contents

1 Measurement specifications

The STC31-C is a highly versatile thermal conductivity sensor for CO2 concentration measurement. For clarity, below table provides relevant information for the most common use cases. For detailed considerations of special cases consult the specific application notes. Examples are controlled atmosphere loggers, fast measurement (*i.e.*, breath cycles) or lowest power operation.

The low-cross-sensitivity measurement mode is the recommended standard mode, and the specifications are provided in section 1.1 below. For the specifications of the low-noise mode, refer to section 1.2.

Every STC31-C is individually tested and calibrated and is identifiable by its unique serial number (see sections 3.3.15 and 4.1).

1.1 Concentration of CO_2 in Air[1] or N_2

Sensor performance in default conditions of 3.3V supply voltage, horizontal orientation, 1 Hz measurement frequency, combined with SHT45 and an accurate pressure sensor; for measurements after forced recalibration (FRC) or automatic self-calibration (ASC)[2] in standard low-cross-sensitivity measurement mode.

Parameter	0-40 vol% or 0-100% CO_2 Range[3]	Note	Conditions
Achievable Accuracy[4,5]	±0.5 (0.2 – 2.0) vol%	Depending on measurement and FRC conditions, assuming ideal design-in	Measurement Range: 0-100 vol% -10-50 °C, 10-95% RH, 800-1200 mbar
Base Accuracy[4,5]	±0.2 vol%	Base accuracy at T, RH and P at which FRC was performed	
Conc. Coefficient (c_C)	0.02 vol% / ΔC (%Conc. CO_2)	additional accuracy error for deviations from FRC conditions	For FRC at 0 vol%, 30 °C, 30% RH, 1000 mbar
Temp. Coefficient (c_T)	0.02 vol% / ΔT[6] (°C)		
Humidity Coefficient (c_{RH})	0.01 vol% / ΔRH (%RH)		
Pressure Coefficient (c_P)	0.001 vol% / ΔP (mbar)		
Resolution	16 bit / 30.5 ppm		
Response time (τ_{63})	< 0.5 s		
Noise[7]	±0.07 vol%	strong filter setting	0 vol%, 20°C 50% RH, 1013 mbar
	±0.32 vol%	no filter	

The STC31-C measures concentration in the unit: volume percent (vol%) of carbon dioxide (CO_2) with respect to the standard conditions: 25°C and 1000 mbar. Volume percent is here defined as volume of the dry constituent divided by the sum of the volumes of all dry constituents of the mixture prior to mixing, multiplied by 100.

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[1] Air is defined as 78.1% nitrogen, 21.0% oxygen and 0.9% argon.

[2] FRC and ASC are comparable to baseline correction or zeroing functions of NDIR and other sensors.

[3] Measurement range and measurement mode can be chosen by setting the gas model as described in 3.3.2 The advantage of the 0-40% range is the reduced sensitivity to input errors. See section 2.1.

[4] Accuracy refers to averaged measurements, excluding noise. Error given for the statistical 2σ range, *i.e.* 95% of parameter combinations and measurements.

[5] Accuracy specifies the performance of the sensor after FRC was performed. Drift over time needs to be evaluated in the specific application environment.

[6] ΔC: concentration deviation from FRC setpoint in % volume concentration; ΔT: temperature deviation from FRC setpoint in °C; ΔRH: relative humidity deviation from FRC setpoint in %RH; ΔP: pressure deviation from FRC setpoint in millibar.

[7] Error given for the statistical 2σ range, *i.e.* 95% of consecutive measurements. Smoothing filters available on chip, see Section 3.3.9.

1.1.1 Total accuracy calculation:

$$\text{Total typical accuracy} = \pm(\text{Base Accuracy} + c_C * \Delta C + c_T * \Delta T + c_{RH} * \Delta RH + c_P * \Delta P)$$

1.1.2 Example for accuracy calculation:

Product initialized and sensor FRC performed at conditions: 400 pm CO_2 (0.04%), 20°C, 50%RH, 1000 mbar. Sensor target conditions for measurement: 10 vol% CO2 in a cold (0°C) and dry (10% RH) environment with possible elevation up to 2000 m and 800 mbar. Accuracy is calculated by assuming worst case scenarios for each parameter:

Typical base accuracy:		0.2 vol%	= 0.2 vol%
additional concentration error:	$c_C * \Delta C$ =	0.02 vol% * (10% – 0.04%)	= 0.2 vol%
additional temperature error:	$c_T * \Delta T$ =	0.02 vol% * (20 – 0)	= 0.4 vol%
additional RH error:	$c_{RH} * \Delta RH$ =	0.01 vol% * (50% – 10%)	= 0.4 vol%
additional pressure error:	$c_P * \Delta P$ =	0.001 vol% * (1000 – 800)	= 0.2 vol%

Total typical accuracy = 0.2 + 0.2 + 0.4 + 0.4 + 0.2 = ±1.4 vol%

1.2 Low-noise measurement mode specifications

The following specifications for the low-noise measurement mode are adopted without change from the STC31 Datasheet V1.1 and are still valid for the new "C" version of the STC31-C.
The new standard low-cross-sensitivity measurement mode is the recommended mode for most applications; however, the low-noise mode might offer some advantages in specific cases.

See also the revision notice in section 7 and unit of measurement in section 1.1.

Low-noise measurement mode		
Parameter	**Value**	
Calibrated for[8]	CO_2 in N_2 and CO_2 in air[9]	
Measurement range[10]	0 to 25 vol%	0 to 100 vol%
Span Accuracy[11]	0.5 vol% + 3% measured value	1 vol% + 3% measured value
Noise[12]	< 0.2 vol%	
Temperature stability[13]	0.025 vol% / °C	
Resolution	16 bit	
Response time (τ_{63})	< 0.5 s	

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[8] Specifications are only valid for these binary gas mixtures (air is interpreted as being one type of gas).
[9] Air is defined as 78.1 vol% nitrogen, 21.0 vol% oxygen and 0.9 vol% argon.
[10] Measurement mode and range can be chosen by setting the gas model as described in 3.3.2
[11] Accuracy is defined after performing FRC at 0 vol% providing a correct temperature, humidity, and pressure measurement. Consult sections 3.3.3, 3.3.4, 3.3.5 and 3.3.7. for detailed information. Fulfilled by 90% of sensors after calibration.
[12] Error given for the statistical 2σ range, *i.e.* 95% of consecutive measurements. Smoothing filters available on chip, see Section 3.3.9.
[13] Slope of CO2 accuracy tolerance after correct temperature compensation when changing temperature compared to the temperature at which the FRC has been performed. Fulfilled by 90% of sensors after calibration. Valid for the temperature range of 0 – 50°C.

2 Sensor specifications

2.1 Sensitivity to compensation inputs of low-cross-sensitivity mode

The STC31-C should be provided with inputs for temperature (T), relative humidity (RH) and pressure (p) to compensate environmental conditions – see Sections 3.3.3 to 3.3.5. Without external input, the sensor will take its internal temperature and assume RH=0%, p=1013 mbar. Inaccurate environmental inputs affect the STC31-C output, by an amount which depends on the selected measurement mode. The table below describes the additional inaccuracies resulting from errors of the input parameters in the vicinity of the true values.

Condition	Selected Range	Typical additional STC31-C output error (vol.%) due to:		
		0.1°C error in T	1% error in RH	1 mbar error in p
T=30 °C, RH=30%, p=1000 mbar, c=0.0%	0-40 vol%	0.025	0.0002	0.0001
	0-100 vol%	0.06	0.04	0.01

The sensitivity to errors in the compensation inputs is significantly higher for the low-noise mode.

2.2 Temperature

The measured temperature is the temperature of the bulk silicon in the sensor. This temperature value is not only depending on the gas temperature, but also on the sensor's contact surface (PCB) and other surroundings. See the Engineering Guide for more details. Values are determined for the measurement frequency of 1 Hz.

Parameter	Value
Measurement range	-40 °C to 105 °C
Resolution	16 bit
Accuracy	0.5 °C (25 °C to 60 °C), 1.0 °C (10 °C to 90 °C), 1.5 °C (-30 °C to 100 °C), 2.0 °C (-40 °C to 105 °C)
Repeatability	0.1 °C

2.3 Electrical specifications

Parameter	Symbol	Condition	Min.	Typ.	Max.	Units
Supply Voltage	V_{DD}		2.7	3.3	5.5	V
Power-up/down level	V_{POR}		2.3	2.5	2.7	V
Supply current	I_{DD}	Measuring		3	5	mA
		Idle state		50		uA
		Sleep mode			1	uA

2.4 Timings

Parameter	Symbol	Typ.	Max.	Units	Comments
Power-up time	t_{PU}		14	ms	Time to sensor ready
Soft reset time	t_{SR}		12	ms	Time between soft reset command or exit sleep mode and sensor ready
I2C SCL frequency	f_{I2C}	400	1000	kHz	
Low-cross-sensitivity concentration measurement duration			110	ms	Measurement result is returned together with temperature value
Low-noise concentration measurement duration			66	ms	

Parameter	Symbol	Typ.	Max.	Units	Comments
Low-cross-sensitivity mode recommended sampling frequency		1	7	Hz	A higher readout frequency (limited by measurement duration) will lead to self-heating and should be consistent during FRC as well as measurement.
Low-noise mode recommended sampling frequency		1	10	Hz	

2.5 Mechanical specifications

Parameter	Symbol	Typ.	Max.	Units	Comments
Weight	W		0.025	g	

2.6 Materials

Parameter	
REACH, RoHS	REACH and RoHS compliant

2.7 Absolute minimum and maximum ratings

Parameter	Rating	Units
Supply Voltage V_{DD}	-0.3 to 5.5	V
Max Voltage on pins (SDA, SCL)	-0.3 to V_{DD}+0.3	V
Input current on any pin	±70	mA
Operating temperature range	-40 to +105	°C
Maximum short term storage temperature range	-40 to +105	°C
Recommended storage temperature range	-10 to +40	°C
Operating absolute pressure range	200 to 2000	mbar
Max. humidity for long term exposure	40 °C dew point	
ESD HBM (human body model)	2	kV
Media Compatibility	Noncorrosive gases	

3 Sensor operation

The STC3x interface is compatible with the I^2C protocol in Standard-mode, Fast-mode and Fast-mode Plus. Clock stretching is not supported. This chapter describes the command set for STC31-C. For detailed information about the I^2C protocol, please check the document "NXP I^2C-bus specification and user manual".
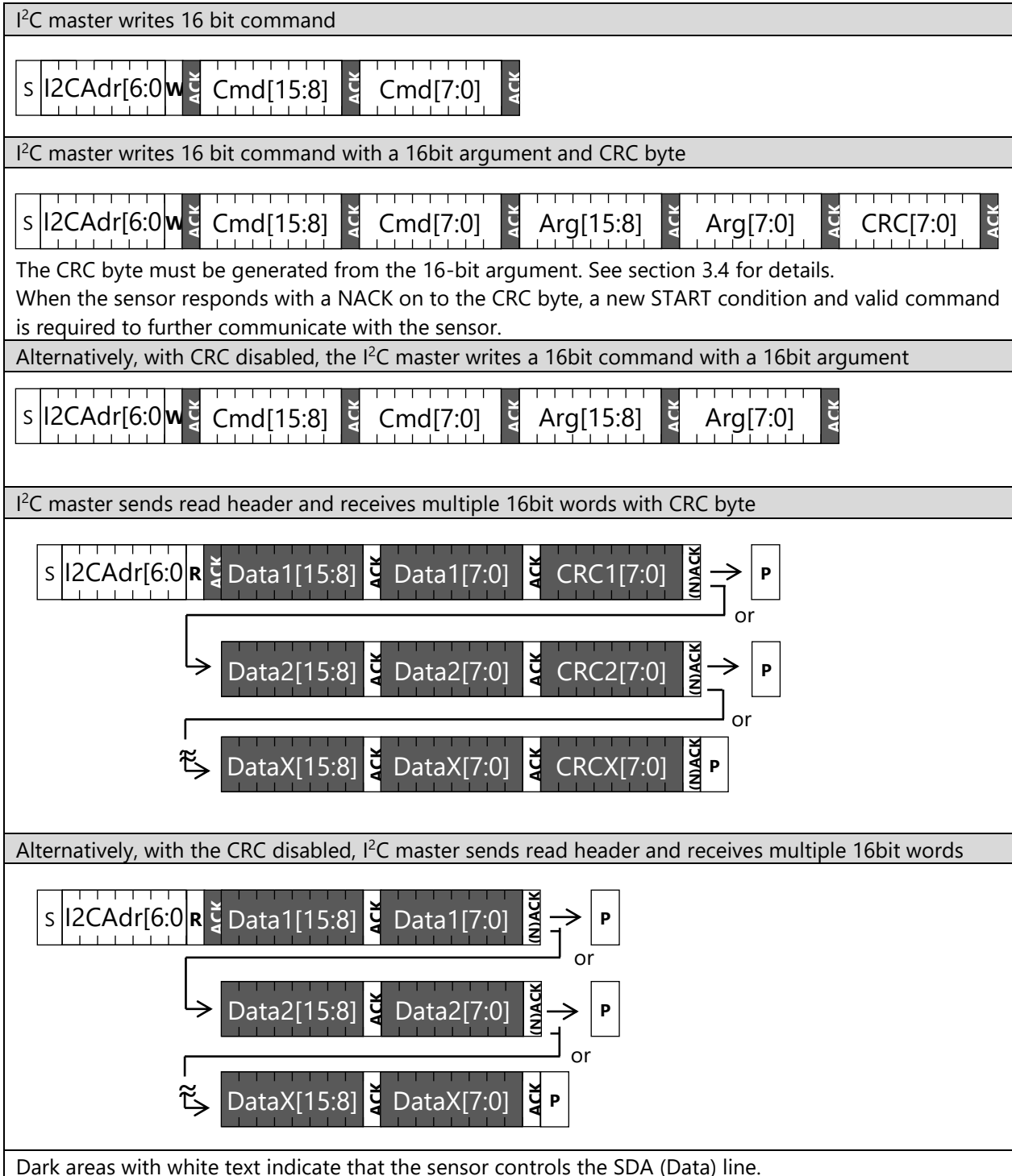
3.1 I^2C addresses

The address is followed by a read or write bit. See section 4.3.3 for selecting alternative I^2C addresses.

I^2C address	in hex. representation	Binary representation
default	0x29	b 010 1001
selectable	0x2A	b 010 1010
selectable	0x2B	b 010 1011
selectable	0x2C	b 010 1100

3.2 I²C sequences

The commands are 16-bit. Data is read from the sensor in multiples of 16-bit words, each followed by an 8-bit checksum to ensure communication reliability. I²C sequences can be aborted with a NACK and STOP condition.

I²C master writes 16 bit command

| S | I2CAdr[6:0] | W | ACK | Cmd[15:8] | ACK | Cmd[7:0] | ACK |

I²C master writes 16 bit command with a 16bit argument and CRC byte

| S | I2CAdr[6:0] | W | ACK | Cmd[15:8] | ACK | Cmd[7:0] | ACK | Arg[15:8] | ACK | Arg[7:0] | ACK | CRC[7:0] | ACK |

The CRC byte must be generated from the 16-bit argument. See section 3.4 for details.
When the sensor responds with a NACK on to the CRC byte, a new START condition and valid command is required to further communicate with the sensor.

Alternatively, with CRC disabled, the I²C master writes a 16bit command with a 16bit argument

| S | I2CAdr[6:0] | W | ACK | Cmd[15:8] | ACK | Cmd[7:0] | ACK | Arg[15:8] | ACK | Arg[7:0] | ACK |

I²C master sends read header and receives multiple 16bit words with CRC byte

| S | I2CAdr[6:0] | R | ACK | Data1[15:8] | ACK | Data1[7:0] | ACK | CRC1[7:0] | (N)ACK | → | P |

or

| Data2[15:8] | ACK | Data2[7:0] | ACK | CRC2[7:0] | (N)ACK | → | P |

or

| DataX[15:8] | ACK | DataX[7:0] | ACK | CRCX[7:0] | (N)ACK | P |

Alternatively, with the CRC disabled, I²C master sends read header and receives multiple 16bit words

| S | I2CAdr[6:0] | R | ACK | Data1[15:8] | ACK | Data1[7:0] | (N)ACK | → | P |

or

| Data2[15:8] | ACK | Data2[7:0] | (N)ACK | → | P |

or

| DataX[15:8] | ACK | DataX[7:0] | ACK | P |

Dark areas with white text indicate that the sensor controls the SDA (Data) line.

3.3 I²C commands

The command set of the STC31-C consists of a set of different commands:

Command	Command code (hex)	Section
Disable CRC	0x3768	3.3.1
Set measurement mode and binary gas	0x3615	3.3.2
Set relative humidity	0x3624	3.3.3
Set temperature	0x361E	3.3.4
Set pressure	0x362F	3.3.5
Measure gas concentration	0x3639	3.3.6
Forced recalibration (FRC)	0x3661	3.3.7
Automatic self-calibration (ASC)	-	3.3.8
Configure noise filter	-	3.3.9
Self-test	0x365B	3.3.10
Soft reset	-	3.3.11
Prepare and read state	0x3752, 0xE133	3.3.12
Write and apply state	0xE133, 0x3650	3.3.12
Read offset value	0x370A	3.3.13
Write offset value	0x3608	3.3.13
Enter sleep mode	0x3677	3.3.14
Exit sleep mode	-	3.3.14
Read product identifier	0x367C, 0xE102	3.3.15

3.3.1 Disable CRC

By default, the arguments written to the sensor and the data coming from the sensor are protected by CRC (cyclic redundancy check). There may be cases where it is beneficial to disable the CRC, for example to reduce the sensor overhead and general power consumption, or during the first stages of development.

In cases where the MCU and sensor are not close together on a PCB, and are for example connected with a wire, it is recommended to not disable the CRC. For safety related applications it is strongly recommended not to disable the CRC.

Command	Command code (hex)	Description
Disable CRC	0x3768	This command disables the CRC on the data for both read and write. See section 3.2 for more details.

When the system is reset or wakes up from sleep mode, the CRC mode is reset to its default value: enabled.

3.3.2 Set measurement mode and binary gas

The STC31-C measures the concentration of binary gas mixtures. It is important to note that the STC31-C is not selective for gases, and it assumes that the binary gas is set correctly. The sensor can only give a correct concentration value when only the gases set with this command are present.

Standard measurement modes (low-cross-sensitivity):

Set binary gas	Range of CO_2	Command code (hex)	Argument (hex)	Output of measurement command (see 3.3.6)
CO_2 in N_2	0 to 100 vol%	0x3615	0x0010	CO_2 concentration between 0 to 100 vol% in N_2
CO_2 in air			0x0011	CO_2 concentration between 0 to 100 vol% in air
CO_2 in N_2	0 to 40 vol%		0x0012	CO_2 concentration between 0 to 40 vol% in N_2
CO_2 in air			0x0013	CO_2 concentration between 0 to 40 vol% in air

Low-noise measurement modes:

Set binary gas	Range of CO_2	Command code (hex)	Argument (hex)	Output of measurement command (see 3.3.6)
CO_2 in N_2	0 to 100 vol%	0x3615	0x0000	CO_2 concentration between 0 to 100 vol% in N_2
CO_2 in air			0x0001	CO_2 concentration between 0 to 100 vol% in air
CO_2 in N_2	0 to 25 vol%		0x0002	CO_2 concentration between 0 to 25 vol% in N_2
CO_2 in air			0x0003	CO_2 concentration between 0 to 25 vol% in air

The command sequence needs to be closed off with a valid CRC byte for the 16-bit argument if the CRC is not disabled. When the CRC byte does not match the argument, the sensor will respond with a NACK and no gas will be selected.
When the system is reset or wakes up from sleep mode, no binary gas is selected (default). This means that the binary gas must be reconfigured.

When no binary gas is selected (default), the consecutive read after a "measure gas concentration" command will return a NACK. This allows to detect unexpected sensor interruption (*e.g.*, due to temporary power loss).

3.3.3 Set relative humidity

Accurate concentration measurement requires compensation of humidity because the measurement principle of the concentration measurement is dependent on the humidity of the gas. The new low-cross-sensitivity mode reduces this sensitivity by smart internal compensation to a minimum. If possible, it is still recommended to compensate for relative humidity with the SHT4x and to update the compensation input whenever the relative humidity changes significantly (see Engineering Guide).

Command	Command code (Hex)	Argument	Description
Set relative humidity	0x3624	Relative Humidity: 16bit unsigned integer For relative humidity scaling, see section 3.5.3.	When no value is written to the sensor after a soft reset, wake-up or power-up, a relative humidity of 0% is assumed. The value written to the sensor is used until a new value is written to the sensor.

This command sequence needs to be closed off with a valid CRC byte for the 16-bit argument if the CRC is not disabled.
When the CRC byte does not match the argument, the sensor will respond with a NACK. The sensor will omit the command and will use the previous value, or when no value was written, assume a relative humidity of 0%.

3.3.4 Set temperature

Accurate concentration measurement requires a compensation of temperature. It is recommended to use the temperature value of the SHT4x, because it is more accurate. When no value has been written since start-up, the sensor uses the internal temperature signal. The temperature compensation input must be updated whenever the temperature changes significantly (see Design Guide).

Command	Command code (hex)	Argument	Description
Set temperature	0x361E	Temperature: 16bit signed integer (two's complement number) For temperature scaling, see section 3.5.2.	When no value is written to the sensor after a soft reset, wake-up or power-up, the internal temperature signal is used. The value written to the sensor is used until a new value is written to the sensor.

This command sequence needs to be closed off with a valid CRC byte for the 16-bit argument if the CRC is not disabled.
When the CRC byte does not match the argument, the sensor will respond with a NACK. The sensor will omit the command and will use the previous value, or when no value was written, the internal temperature signal.

3.3.5 Set pressure

The concentration measurement requires compensation of pressure. With the *set pressure* command, the sensor uses the input to compensate the concentration results. The pressure should be updated just before a new measurement is started.

Pressure compensation is valid from 600 mbar to 1500 mbar.

Command	Command code (hex)	Argument	Description
Set pressure	0x362F	Absolute pressure: 16bit unsigned integer For pressure scaling, see section 3.5.4.	When no value is written to the sensor after a soft reset, wake-up or power-up, a pressure of 1013mbar is assumed. The value written is used until a new value is written to the sensor.

This command sequence needs to be closed off with a valid CRC byte for the 16-bit argument if the CRC is not disabled.

When the CRC byte does not match the argument, the sensor will respond with a NACK. The sensor will omit the command and will use the previous value, or when no value was written, assume the default value of 1013mbar.

3.3.6 Measure gas concentration

The duration of a gas concentration measurement is defined in section 2.4. When measurement data is available, it can be read out by sending an I^2C read header and reading out the data from the sensor. If no measurement data is available yet, the sensor will respond with a NACK on the I^2C read header. The gas model needs to be set once before the measurement command, see 3.3.2.

Command	Command code (hex)	Consecutive read	Description
Measure gas concentration	0x3639	Byte1: Gas concentration 8msb Byte2: Gas concentration 8lsb Byte3: CRC Byte4: Temperature 8msb Byte5: Temperature 8lsb Byte6: CRC Byte7: Reserved 8msb Byte8: Reserved 8lsb Byte9: CRC	The gas concentration is a 16-bit unsigned integer. The temperature and byte 7 and 8 do not need to be read out. The read sequence can be aborted after any byte by a NACK and a STOP condition.

In case the 'Set temperature command' has been used prior to the measurement command, the temperature value given out by the STC31-C will be that one of the 'Set temperature command'. When the 'Set temperature command' has not been used, the internal temperature value can be read out.

During product development it is recommended to compare the internal temperature value of the STC31-C and the temperature value of the SHT4x, to check whether both sensors are properly thermally coupled. The values must be within 0.7°C at room temperature.

3.3.7 Forced recalibration (FRC)

Forced recalibration is used to improve the sensor output with a known reference value. The resulting correction is only valid for the active measurement mode, binary gas and range. See the Design Guide for more details.

If no argument is given, the sensor will assume a default value of 0 vol%. The FRC command takes the same amount of time as the concentration measurement. The measurement rate should be the same during FRC and normal measurement. The FRC correction is lost upon a power cycle and <u>must</u> be stored externally to be feed back to the sensor upon restart (see section 3.3.12).

Command	Command code (Hex)	Argument	Description
Forced recalibration	0x3661	Reference concentration: 16bit unsigned integer	The sensor output is changed to correspond to the reference value given.

This command sequence needs to be closed off with a valid CRC byte for the 16-bit argument if CRC is not disabled. In the case that the CRC byte does not match the argument, the sensor will respond with a NACK and the forced recalibration is performed with the default reference concentration of 0%. In this case FRC must be repeated.

3.3.8 Automatic self-calibration (ASC)

The sensor can run in automatic self-calibration mode. This mode will enhance the accuracy for applications where the target gas is not present for most of the time. See the Design Guide for more details. This feature can be enabled or disabled by using the commands as shown below. The default state is disabled.

Command	Command code (hex)	Argument	Description
Enable automatic self-calibration	0x3FEF	NA	The sensor will apply automatic self-calibration
Disable automatic self-calibration	0x3F6E (default)	NA	The sensor will not apply automatic self-calibration (default)

The automatic self-calibration is optimized for a gas concentration measurement interval of 1s. Substantially different measurement intervals may decrease the self-calibration performance. The ASC correction is lost upon a power cycle, reset, and sleep mode and <u>must</u> can be stored externally to be feed back to the sensor upon restart (see section 3.3.12).

3.3.9 Configure noise filter

The STC31-C has two built-in noise filters that run an exponential smoothing over the past measurement points.

Command	Command code (hex)	Description
Enable weak filter	0x3FC8	Default is disabled. The weak filter has a smoothing factor of 1/2.5. $y[n] = 0.6 * y[n-1] + 0.4 * x$
Disable weak filter	0x3F49	
Enable strong filter	0x3FD5	Default is disabled. The strong filter has a smoothing factor of 1/7.5. $y[n] = 0.867 * y[n-1] + 0.133 * x$
Disable strong filter	0x3F54	

By default, no filter is applied to the data. If smoothing is desired, the following command(s) must be executed once upon starting the sensor. When enabled, the filter is applied for all subsequent concentration measurements.

Please note:
- Both filters can be activated at the same time (chained) for stronger smoothing.
- Forced recalibration (section 3.3.7) can only benefit from this filtering if sufficient measurement points have been taken before executing the FRC.
- The response time (specified in section 1.1) will increase if a noise filter is applied.
- Filtering will not function if the sensor is put to sleep between each concentration measurement, as the last output value is lost.

3.3.10 Self-test

The self-test command runs an on-chip self-test which takes less than 30ms. It performs a full memory integrity check and checks that the operating voltage is within specifications.

Command	Command code (hex)	Consecutive read	Description
Self-test	0x365B	Byte1: Self-test 8msb Byte2: Self-test 8lsb Byte3: CRC	The sensor will run an on-chip self-test. A successful self-test will return b00 for the two least significant bits.

The self-test errors are decoded as follows:

Bits	Error State
1:0	Memory error
9:2	For debugging only
15:10	Always 0

In case of a memory error, the sensor should be *soft-reset* and the self-test should be repeated. If the problem persists, the supply voltage should be cycled to trigger a Power-on-Reset and the self-test should be repeated. If then the problem persists, measurement results might be compromised.

Bits 9:2 should only be considered during design-in and is for debugging purposes.
During design-in and debugging, the self-test should be performed during stable conditions, i.e. stable and noise free supply voltage, and a stable pressure, humidity and temperature. If one or more bits return 1, contact Sensirion for support.

3.3.11 Soft reset

Command	I^{2}C address + W bit + command code (hex)	Consecutive read	Description
General call reset	0x0006	NA	This sequence resets the sensor with a separate reset block, which is as much as possible detached from the rest of the system on chip. Note that the I^{2}C address is 0x00, which is the general call address, and that the command is 8 bit. The reset is implemented according to the I^{2}C specification.

After the reset command the sensor is in the same state as after a power up cycle. Reset takes a maximum of 12ms. During this time the sensor will not acknowledge its address nor accept commands.

3.3.12 Sensor state retention

The sensor stores settings like the gas model or reference values of FRC and ASC in volatile memory. These are not retained when the sensor loses power and must be stored externally to be sent to the sensor after each power cycle.
To store the state of the sensor externally use the following two commands
1. Prepare read state
2. Read state

Check the CRC of the state and store the 30 bytes. After each power cycle return the state to the sensor by using the two commands
1. Write state
2. Apply state

The sensor state contains the following information:
- Selected binary gas index (see 3.3.2)
- ON or OFF flag and offset value to apply to the sensor's output for the ASC (automatic self-calibration, see 3.3.8)
- Offset value to apply to the sensor's output used in FRC and ASC (forced recalibration, see 3.3.7)
- Compensation inputs: last supplied values of temperature (see 3.3.4), humidity (see 3.3.3) and pressure (see 3.3.5)

Remark on what is **not** part of the sensor state:
- If CRC disabling is desired, it needs to be disabled after each wake-up
- The noise filter (see section 3.3.9) is not saved in the sensor state and therefore, this filtering cannot be used in combination with sleep mode.

Command	Command code (hex)	Consecutive read	Description
Prepare read state	0x3752	NA	The sensor will prepare its current state to be read out. Please wait 2 ms before sending the next command.
Read state	0xE133	30 bytes (10 times 16-bit word + CRC)	Read out the sensor state. The 30 bytes must be stored on the microcontroller to be written back to the sensor after exiting sleep mode

Command	Command code (hex)	Argument	Description
Write state	0xE133	30 bytes (10 times 16-bit word + CRC)	Write the sensor state as read out earlier with the "Read state" (0xE133) command.
Apply state	0x3650	NA	The sensor will apply the written state data. Please wait 2 ms before sending the next command.

It is important to check that no corrupted state is applied to the sensor. Therefore, abort the process as soon as a NACK is received during the Read state or Write state commands. Example procedures of sensor state retention can be found in the Design Guide.

3.3.13 Alternative FRC persistence

When using FRC, the read and write offset value commands can be used to persist only the offset value used for FRC. All other settings, like the binary gas index must be set with the separate commands.

Command	Command code (hex)	Consecutive read / argument	Description
Read offset value command	0x370A	16 bits	Returns a single value with the most significant 16 bits of the offset value.
Write offset value command	0x3608	16 bits	Expects the most significant 16 bits of the offset value as an I2C command argument.

Note that this is not suitable for ASC in combination with sleep mode, because the least significant bits of the offset value are lost.

3.3.14 Sleep mode

In sleep mode the sensor uses the minimum amount of current. The mode can be entered when no other command is running. This mode is particularly useful for battery operated devices.

Implement and test the *Sensor state retention* sequence as described in section 3.3.13 before implementing the sleep sequence.
For the sensor state retention, a sleep mode is equivalent to a power cycle. Follow the procedure in section 3.3.13 to keep settings and FRC and ASC values.
Since the noise filter state is not part of the state retention it cannot be used in combination with the sleep mode.

In sleep mode the sensor cannot be soft reset.

Command	Command code (hex)	Consecutive read	Description
Enter Sleep mode	0x3677	NA	The sleep command can be sent anytime, whenever no other command is running.
Exit Sleep mode	NA	NA	The sensor exits the sleep mode when it receives the **valid I²C address and a write bit ('0').** Note that the I²C address is **not** acknowledged. It is possible to poll the sensor to see whether the sensor has received the address and has woken up. This takes maximum 12ms.

3.3.15 Read product identifier

During assembly and start-up of the device it might be required to check some basic parameters in the sensor - for example to check if the correct sensor is integrated.
The product identifier and serial number can be read out after sending a sequence of two commands.

Command	Command code (hex)	Consecutive read	Description
Read product identifier	0x367C 0xE102	Byte1: Product number [31:24] Byte2: Product number [23:16] Byte3: CRC Byte4: Product number [15:8] Byte5: Product number [7:0] Byte6: CRC Byte7: Serial number [63:56] Byte8: Serial number [55:48] Byte9: CRC Byte10: Serial number [47:40] Byte11: Serial number [39:32] Byte12: CRC Byte13: Serial number [31:24] Byte14: Serial number [23:16] Byte15: CRC Byte16: Serial number [15:8] Byte17: Serial number [7:0] Byte18: CRC	Note that both commands need to be preceded with an I2C write header (I2C address + W). The second command returns: - 32-bit unique product and revision number. The number is listed in the table below. *Note that the last 8 bits are the revision number and can be subject to change.* - 64-bit unique serial number as ASCII representation of the serial number on the sensor.

Product	Product number
STC31-C	0x08010304

3.4   Checksum calculation

The checksum byte is generated by a CRC algorithm with the following properties:

Property	Value
Name	CRC-8
Protected data	read data
Width	8 bit
Polynomial	0x31 ($x8 + x5 + x4 + 1$)
Initialization	0xFF
Reflect input	False
Reflect output	False
Final XOR	0x00
Example	CRC(0xBEEF) = 0x92

3.5 Conversion to physical values

3.5.1 Gas concentration

The digital calibrated gas concentration signal read from the sensor is an unsigned integer number. The integer value can be converted to the physical value by the following conversion formula.

$$Concentration\ [vol\ \%] = \frac{STC3x\ output - 2^{14}}{2^{15}} \times 100$$

Example: 32000 => 47.7% volume concentration for the selected gas.

3.5.2 Temperature

The digital calibrated temperature signal read from or written to the sensor is a signed integer number (two's complement number). The integer value can be converted to the physical value by the following conversion formula.

$$Temperature\ [°C] = \frac{STC3x\ output\ or\ input}{200}$$

Example: 2500 => 12.5°C

3.5.3 Relative humidity

The relative humidity value written to the sensor is an unsigned integer number. The integer value can be converted to the physical value by the following conversion formula.

$$Relative\ Humidity\ [\%] = \frac{STC3x\ input \times 100}{2^{16} - 1}$$

Example: 65535 => 100% relative humidity

3.5.4 Pressure

The pressure value written to the sensor is an unsigned integer number. The integer value can be converted to the physical value by the following conversion formula.

$$Pressure\ [mbar] = STC3x\ input$$

Example 1023 => 1023 mbar

4 Physical specifications
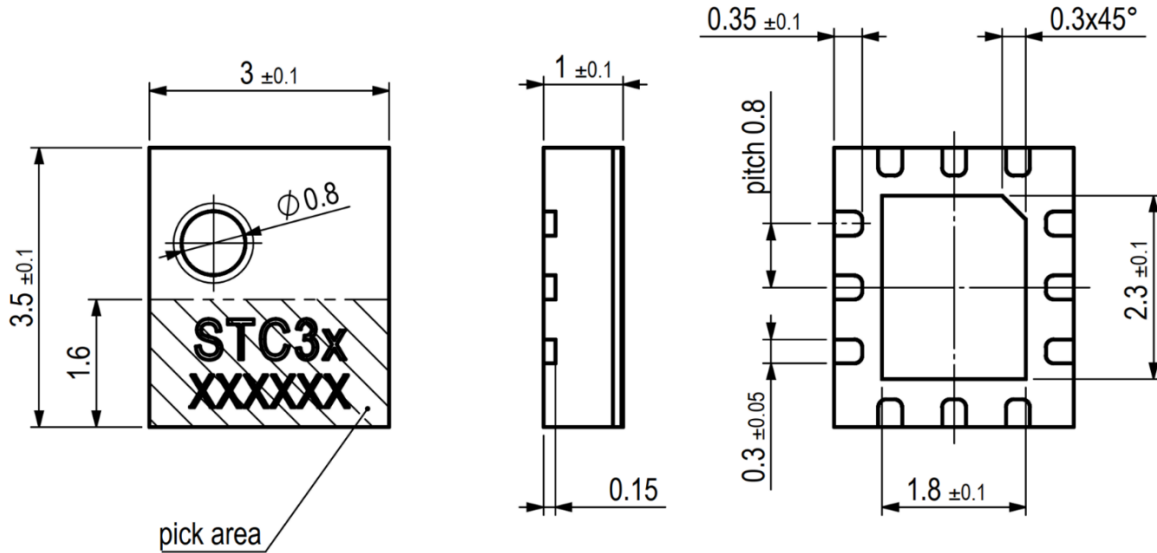
4.1 Package outline

Figure 1 Dimensional drawing of STC3x including package tolerances (units mm). XXXXXX denotes the sensor version "C" + serial number.

4.2 Land pattern

The land pattern is recommended to be designed according to the used PCB and soldering process together with the physical outer dimensions of the sensor. For more details about soldering see separate Handling and Assembly Instructions.
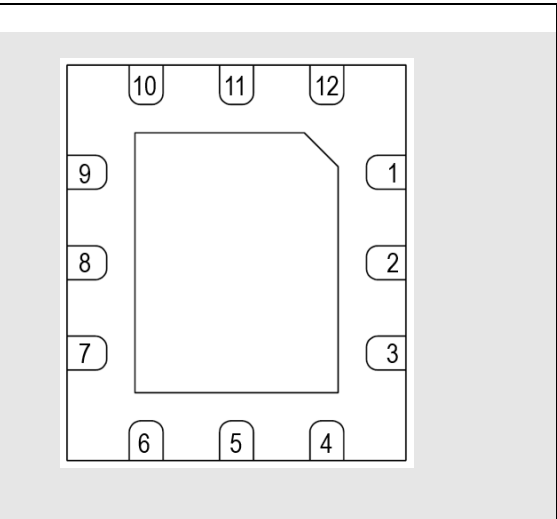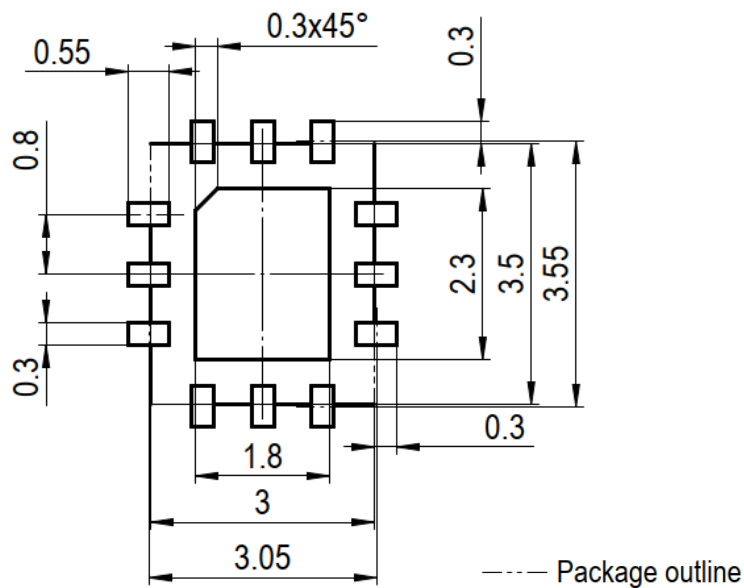

Figure 2 Example Land Pattern: Top View on PCB (through component)

4.3 Pin assignment

The pin assignments of the STC31-C, bottom view.

Pin no.	Name	Description
1	VSS	Connect to ground
2	-	Reserved. Do not connect
3	ADDR	I2C Address Selection
4	SCL	Serial Clock (I^{2}C Interface)
5	VSS	Connect to ground
6	VDD	VDD Supply
7	SDA	Bidirectional Serial Data (I^{2}C Interface)
8	-	Reserved. Do not connect
9	VSS	Connect to ground
10	-	Reserved. Do not connect
11	VSS	Connect to ground
12	-	Reserved. Do not connect

4.3.1 Power pins (VDD, GND)

The power supply pin must be decoupled with a 100 nF capacitor that shall be placed as close to the sensor as possible.

4.3.2 Serial clock and serial data (SCL, SDA)

The SCL and SDA are bidirectional pins of the I^{2}C slave interface. The SCL is the Serial Clock pin and the SDA is the Serial Data pin. For more details about the I^{2}C interface refer to section 3.

Both SCL and SDA lines are open-drain I/Os with diodes to VDD und VSS. They should be connected to external pull-up resistors (please refer to **Figure 3**). A device on the I2C bus must only drive a line to ground. The external pull-up resistors (*e.g.* R$_p$ = 10 kΩ) are required to pull the signal high. For dimensioning resistor sizes please take bus capacity and communication frequency into account (see for example Section 7.1 of NXPs I^{2}C Manual for more details[14]). It should be noted that pull-up resistors may be included in I/O circuits of microcontrollers. It is recommended to wire the sensor according to the application circuit in **Figure 3**.
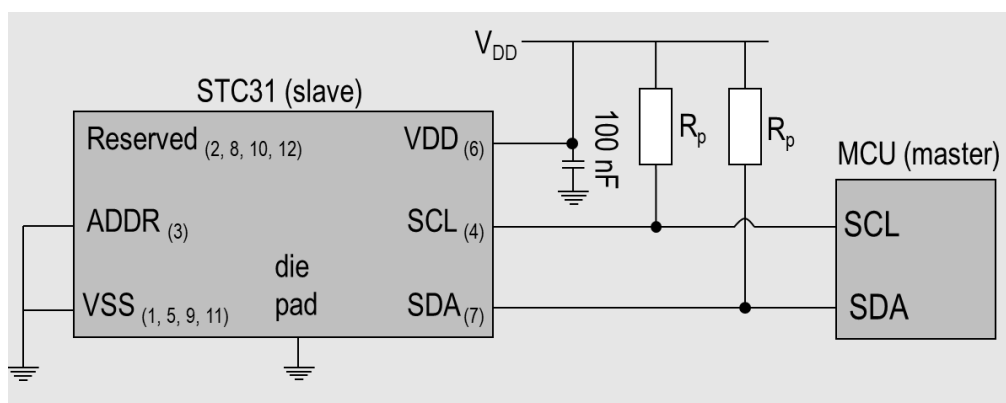

Figure 3 Typical application circuit. *Please note that the positioning of the pins does not reflect the position of the sensor's orientation in the reel. This is shown in section 5. The pin numbers corresponding to the schematic in section 4.3 are indicated.*

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[14] http://www.nxp.com/documents/user_manual/UM10204.pdf

4.3.3 Address selection pin (ADDR)

A resistor between ADDR and VDD may be used to configure the I^{2}C address the STC31-C uses for communication. The selectable addresses and their respective conditions are:

I2C Address (hex)	Condition
0x29 (default)	Ground or no connection between ADDR (pin 3) and VDD (pin 6)
0x2A	10 kOhm (±5%) between ADDR (pin 3) and VDD (pin 6)
0x2B	3.3 kOhm (±5%) between ADDR (pin 3) and VDD (pin 6)
0x2C	1 kOhm (±5%) between ADDR (pin 3) and VDD (pin 6)

4.3.4 Die pad (center pad)

The die pad or center pad is visible from below and located in the center of the package. It is electrically floating and therefore it is recommended to connect it to GND. Depending on the application, it may or may not be advantageous to solder the center pad to a larger ground trace/plane to increase thermal coupling.

5 Shipping package

STC31-C is provided in tape & reel shipment packaging. Available packaging size is 400 or 5000 units per reel.
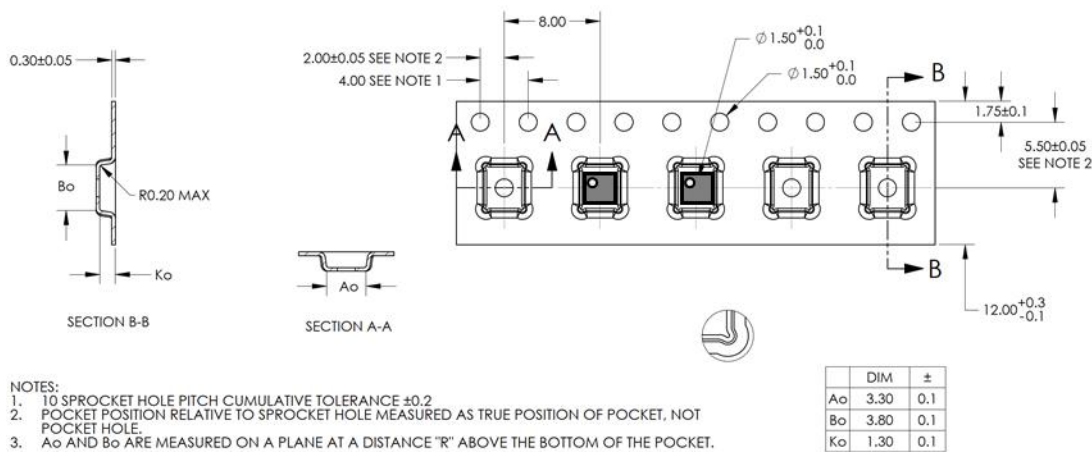

Figure 4 Technical drawing of the packaging tape with sensor orientation in tape. Header tape is to the right and trailer tape to the left on this drawing. Dimensions are given in millimeters.

6 Ordering information

Use the part names and product numbers shown in the following table when ordering STC31-C Thermal Conductivity Sensor. For the latest product information and local distributors, visit www.sensirion.com.

Part name	Description / Output	Order number	Packaging	Tape & reel size
SEK-STC31-C		3.001.061	Single package evaluation kit	n/a
STC31-C-R3	I^{2}C	3.001.031	Tape & Reel	400
STC31-C-R5		3.001.032	Tape & Reel	5000

7   Product revision notice

The development the STC family has resulted in major advances and a new measurement mode with superior cross sensitivity performance is introduced with the 2024 release of the STC31-C.

The STC31-C can be identified visually by the laser marking on the package: STC31 "C". The previously available version of the STC31 was marked with an "A".

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┌─────────────┐
│ ◯           │
│ - - - - - - │
│   STC31     │
│   Cxxxxx    │
└─────────────┘
```
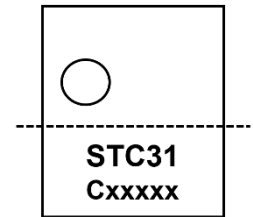
Changes are:
- Introduction of the new standard measurement mode (low-cross-sensitivity) with significantly reduced cross sensitivity to changes in the humidity and oxygen content of the air. The legacy measurement mode (low-noise) is still available with unchanged measurement command for backward compatibility (see below).
- Applies to the new standard low-cross-sensitivity measurement mode:
  - General improvements of the temperature and pressure sensitivity.
  - Improved characterization of the impact of concentration, temperature, humidity and pressure on the measurement accuracy. See section 1.1.
  - Characterization of the sensitivity to errors in the compensation inputs (T, RH, p). See section 2.
  - Extension of the low concentration range from 0-25% to 0-40% CO_2.
  - The new standard measurement mode (low-cross-sensitivity) has more noise on the individual measurement than the low-noise measurement mode. This can be resolved by averaging multiple measurements or using the filter setting.
- Detailed characterization of the temperature sensor accuracy. See section 2.2.
- Increased absolute minimum and maximum temperature ranges. See section 2.7.
- In contrast to STC31, STC31-C's center pad is not connected to ground, and it is recommended to solder it to ground and not let it floating.

Backward compatibility:
- The STC31-C is fully backward compatible to the STC31.
- There are no changes in the physical properties of the component and shipping package.
- There are no changes in the electrical interface or digital communication.
- The new standard measurement mode (low-cross-sensitivity) is now available under a new measurement command argument (see section 3.3.2) and does not overwrite the legacy measurement mode (low-noise).
- The low-noise measurement mode remains available with the same measurement command argument and there is no change of the communication required to continue using it when transitioning from STC31 to STC31-C.
- The new measurement mode (low-cross-sensitivity) seems to perform better for all applications known to us. We recommend all customers to evaluate it. However, no end of life of the old measurement mode is planned.
- The unchanged specifications for the low-noise mode are provided unchanged in section 1.2.

8 Revision history

Date	Version	Pages / Sections	Changes
Oct 2020	1.1	all	Last Datasheet for STC31
April 2024	3.0	all	First release for STC31-C • Finalized specifications in section 1.1, 1.1.1, 1.1.2, and 2.1 • Typos and cross-references corrected • Correct hyphenation: "low-cross-sensitivity" and "low-noise" • QR-Code for feedback added • FRC conditions at one point • Added: Measurement rate should be the same during FRC and normal measurement. • Final Product Number: 0x08010304, section 3.3.15 • Section 3.3.3, 3.3.4, 3.3.5 updated with recommendations and Design Guide • Section 4.3.4: New note about the requirement and option to solder the center pad to a large ground trace/plane.
June 2024	3.1	all	Minor corrections
		3.3.10	Chapter Self Test rewritten with new recommendations
		1.1	Precise definition for measurement unit vol% added
		4.2	Land pattern recommendation added
		3.3.2 – 3.3.6	Wording and clarity of text
Sept. 2024	3.2	all	Minor corrections of spelling and format
		3.2	Added additional information for handing NACK response to CRC byte
		3.3.7	Added clarification: The resulting correction is only valid for the active measurement mode, binary gas and range.

Important Notices

Warning, Personal Injury

Do not use this product as safety or emergency stop devices or in any other application where failure of the product could result in personal injury. Do not use this product for applications other than its intended and authorized use. Before installing, handling, using or servicing this product, please consult the data sheet and application notes. Failure to comply with these instructions could result in death or serious injury.

If the Buyer shall purchase or use SENSIRION products for any unintended or unauthorized application, Buyer shall defend, indemnify and hold harmless SENSIRION and its officers, employees, subsidiaries, affiliates and distributors against all claims, costs, damages and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if SENSIRION shall be allegedly negligent with respect to the design or the manufacture of the product.

ESD Precautions

The inherent design of this component causes it to be sensitive to electrostatic discharge (ESD). To prevent ESD-induced damage and/or degradation, take customary and statutory ESD precautions when handling this product. See application note "ESD, Latchup and EMC" for more information.

Warranty

SENSIRION warrants solely to the original purchaser of this product for a period of 12 months (one year) from the date of delivery that this product shall be of the quality, material and workmanship defined in SENSIRION's published specifications of the product. Within such period, if proven to be defective, SENSIRION shall repair and/or replace this product, in SENSIRION's discretion, free of charge to the Buyer, provided that:

- notice in writing describing the defects shall be given to SENSIRION within fourteen (14) days after their appearance;
- such defects shall be found, to SENSIRION's reasonable satisfaction, to have arisen from SENSIRION's faulty design, material, or workmanship;
- the defective product shall be returned to SENSIRION's factory at the Buyer's expense; and
- the warranty period for any repaired or replaced product shall be limited to the unexpired portion of the original period.

This warranty does not apply to any equipment which has not been installed and used within the specifications recommended by SENSIRION for the intended and proper use of the equipment. EXCEPT FOR THE WARRANTIES EXPRESSLY SET FORTH HEREIN, SENSIRION MAKES NO WARRANTIES, EITHER EXPRESS OR IMPLIED, WITH RESPECT TO THE PRODUCT. ANY AND ALL WARRANTIES, INCLUDING WITHOUT LIMITATION, WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, ARE EXPRESSLY EXCLUDED AND DECLINED.

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SENSIRION reserves the right, without further notice, (i) to change the product specifications and/or the information in this document and (ii) to improve reliability, functions and design of this product.

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