TECHNICAL USER GUIDE

CO_2 Module EE894
Protocol Description I^2C

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E+E ELEKTRONIK® Ges.m.b.H.

CONTENTS

1 Introduction

EE894 supports the standard I²C specification. For details please see NXP UM10204 „I²C-bus specification and user manual", Rev. 6, 4 April 2014; https://www.nxp.com/docs/en/user-guide/UM10204.pdf.

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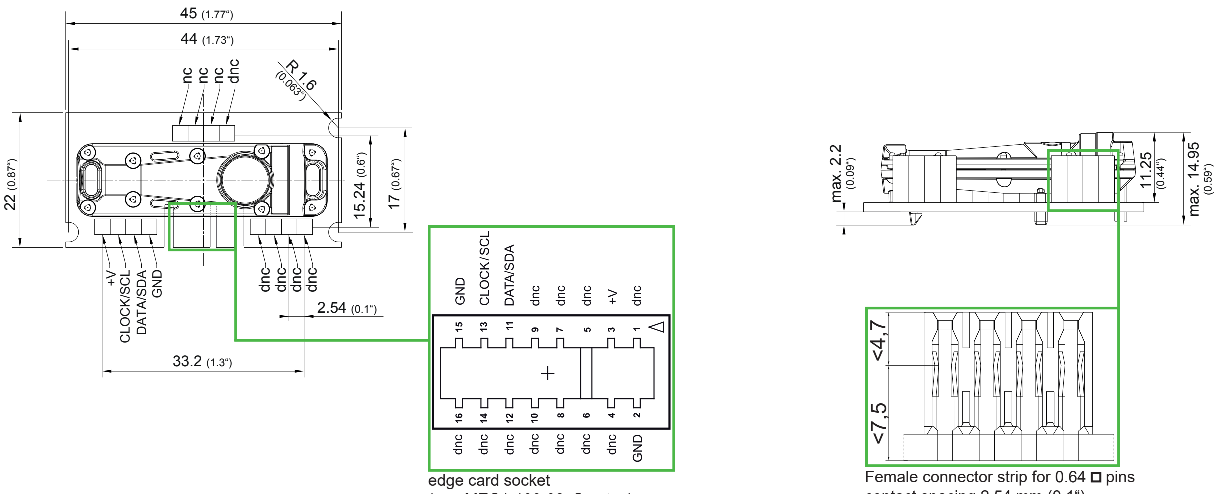
2 Hardware

2.1 Connection Diagram EE894 Compact



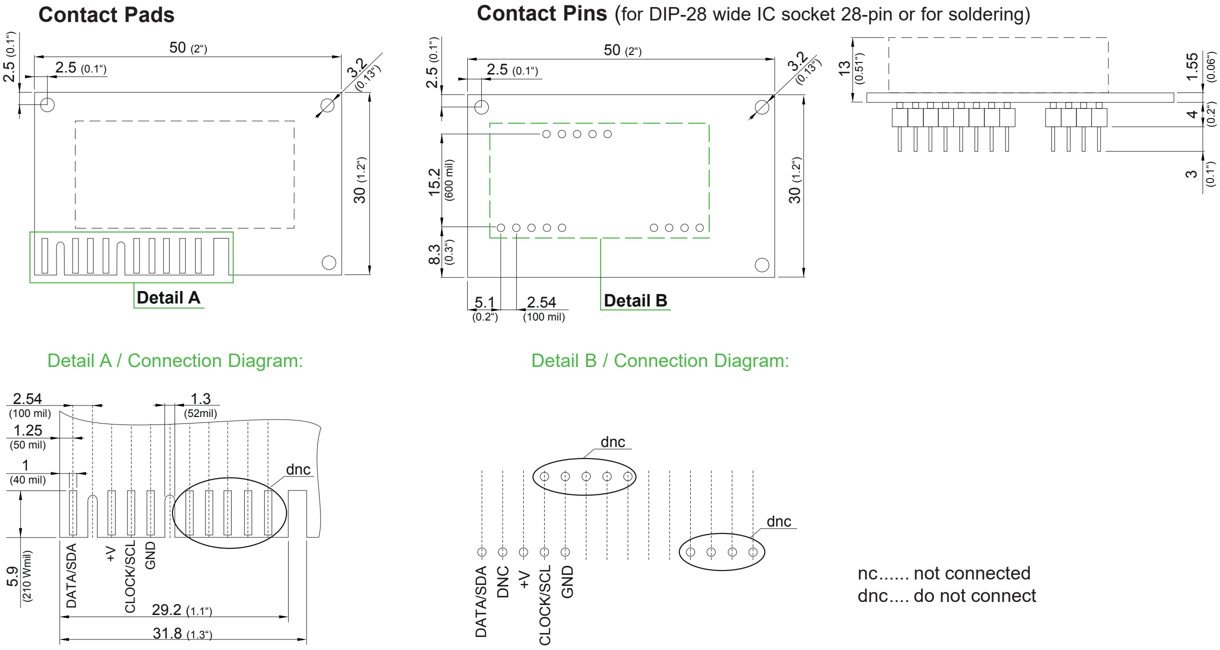
edge card socket
(e.g. MEC1-108-02, Samtec)

Female connector strip for 0.64 ◻ pins
contact spacing 2.54 mm (0.1")

2.2 Connection Diagram EE894 Standard

Contact Pads

Contact Pins (for DIP-28 wide IC socket 28-pin or for soldering)



2.3 Setup

Connection scheme for EE894 with connected bus-high-voltage via two external pull-up resistors.

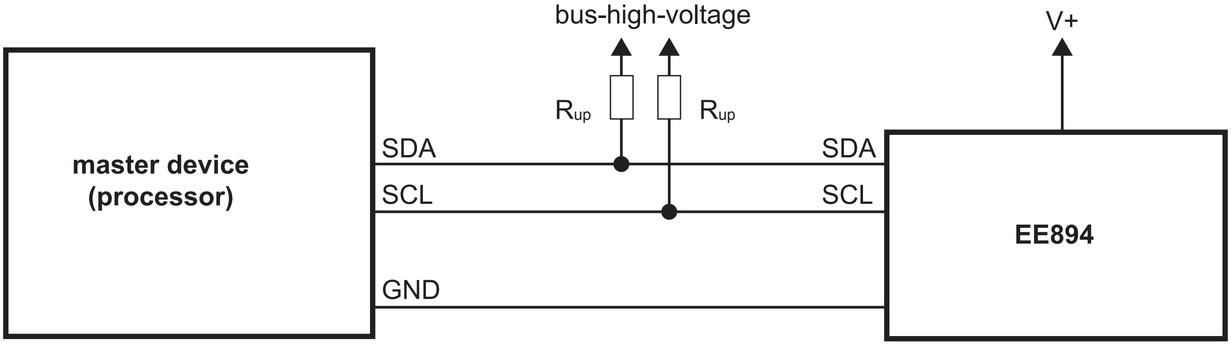


Fig. 1 Hardware master / slave setup

Note:
Observe the compatibility of the voltage levels between the I²C Interface levels and the master processor.

Electrical requirements

Parameter	Minimum	Maximum	Unit	Remark
bus-high-voltage	3.3	5.2	V	
clock frequency	500	100000	Hz	The highest achievable data rate depends on the combination of line capacity and the pull-up resistors.
pull-up resistor	4.7	100	kΩ	

2.4 Timing Details

	Minimum	Typical	Maximum
t_{pwrup}* (power up)	4.7 s		16.2 s
t_{meas} (measurement)		0.8 s	
t_{mti} (measurement time interval) ± 6.25%	15 s		3 600 s

* see chapter 2.5

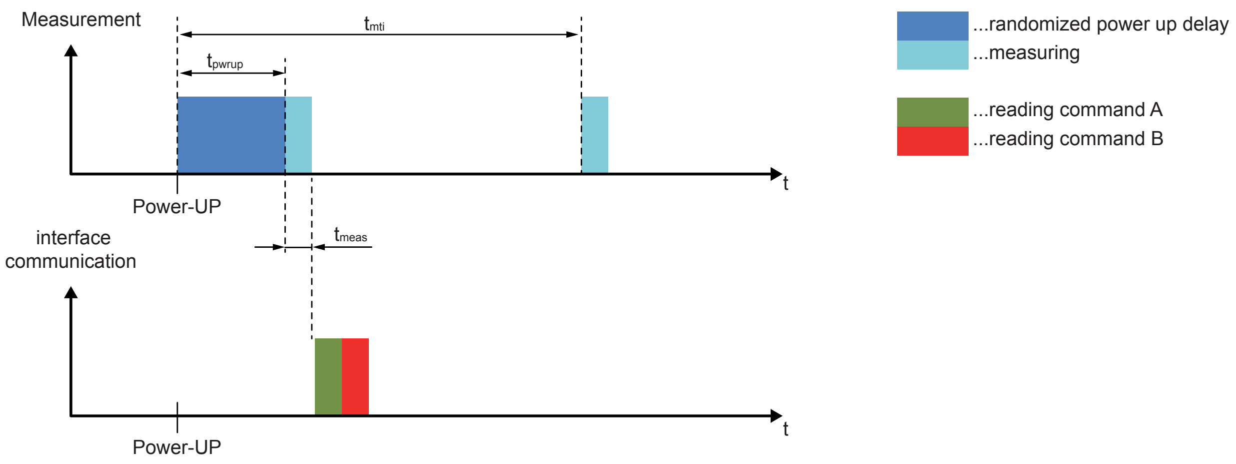


Fig. 2 Timing example

2.5 Power Consumption Details

EE894 module is designed to change its operation mode based on the actual status of measurement or communication. The supply current is different for each operation mode and it is shown given below as well as in Figure 3.

Mode	Supply current	Description
Sleep mode	typ. 410 µA	The module is waiting for measurement or communication request
Warm-up mode	typ. 10 mA	The module is in warm-up mode. Duration 450 ms before a measurement is taken.
Communication mode	typ. 10 mA	Initiated by an interrupt on the I²C Bus and lasts as long as the communication is ongoing
Measuring mode	max. 350 mA	current peak, caused by flashing the infrared lamp. For details see Figure 2.

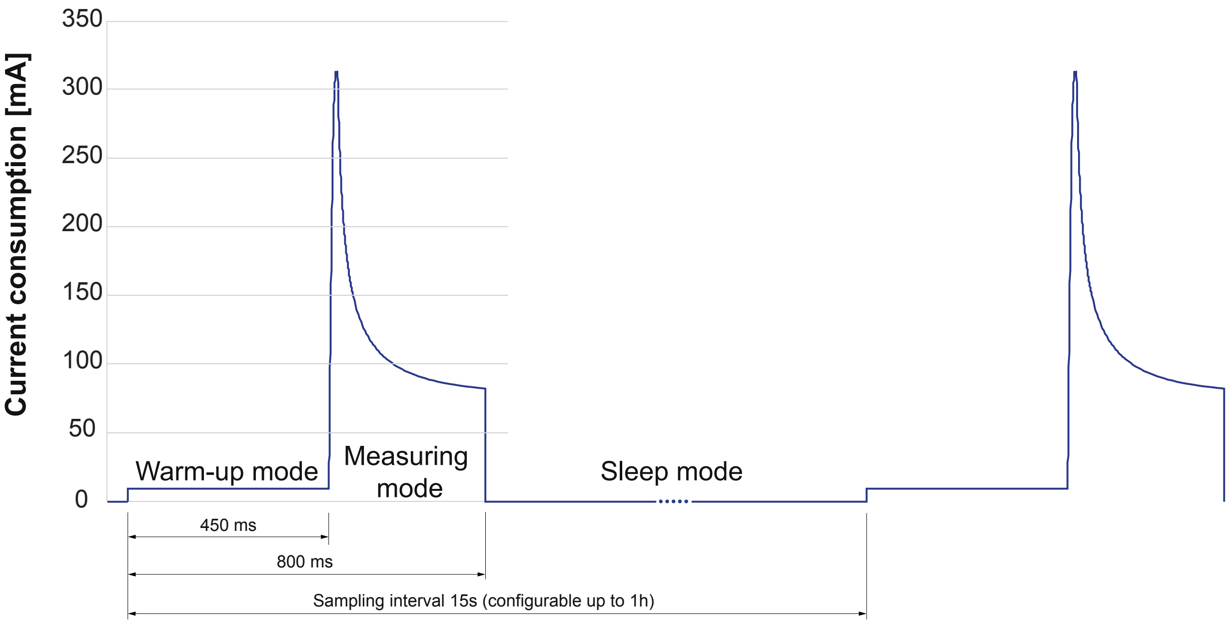


Fig. 3 Power consumption

Setting a longer measuring interval extends the sleep mode time.
After a reset the module starts the first measurement after 5 s to 15 s; the timing (t_{pwrup}) is defined by a randomizer and is specific for each EE894. The randomizer is constant for each power up but varies from module to module.

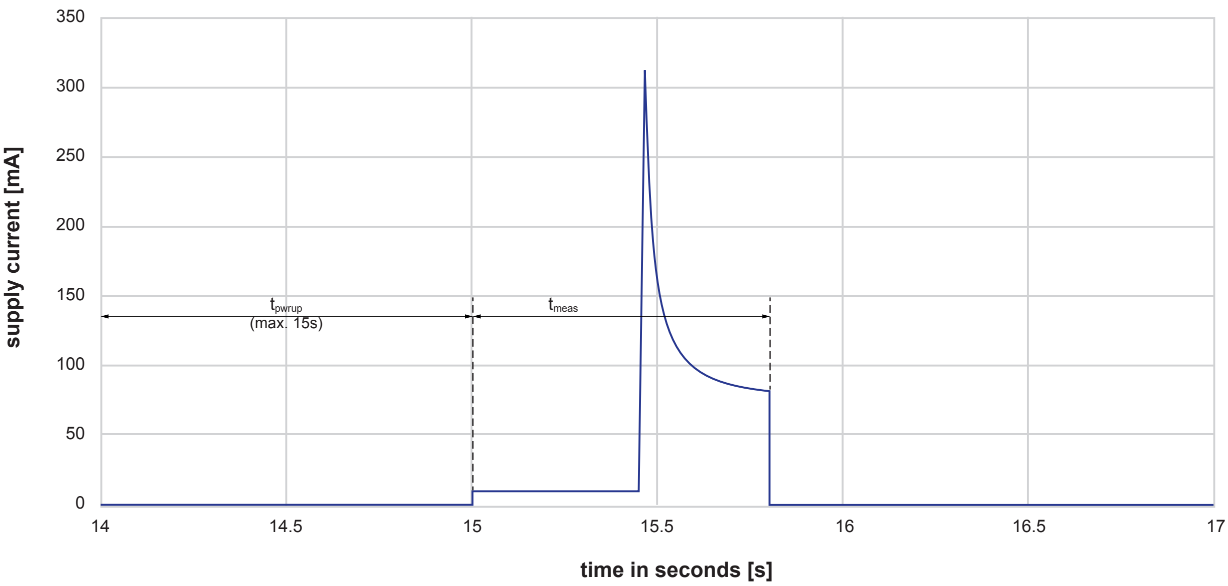


Fig. 4 Supply current in measuring mode @ 23 °C

3 Interface Description

3.1 Protocol

The I²C interface of EE894 supports the “Standard-Mode” up to 100 kbit/s, 8-bit oriented, where the I²C slave address is 7 bit long. The master has to support clock streching (CS).

3.2 Addressing

The slave address is **0x33**. Accordingly, the address byte **0x67** is used to read and **0x66** to write, please refer to the NXP specs section 3.1.10.
The I²C interface of the EE894 module supports reading the measured data as well as writing in the customer memory. List of supported commands:

- **Reading command A: 0xE000**
  Read the temperature value in 0.01 Kelvin and relative humidity value in 0.01 %.

START	I²C ADDRESS - 0x66 (W)	CS	ACK	CMD MSB - 0xE0	ACK	CMD LSB - 0x00	ACK	
S	0 1 1 0 0 1 1 0			1 1 1 0 0 0 0 0		0 0 0 0 0 0 0 0		••

- **Reading command B: 0xE027**
  Read the averaged CO_2 value in 1 ppm, the raw CO_2 value in 1 ppm and ambient pressure in 0.1 mbar

START	I²C ADDRESS - 0x66 (W)	CS	ACK	CMD MSB - 0xE0	ACK	CMD LSB - 0x27	ACK	
S	0 1 1 0 0 1 1 0			1 1 1 0 0 0 0 0		0 0 1 0 0 1 1 1		••

- **Command for customer memory access: 0x7154**
  Command for measurement time configuration and customer adjustment

START	I²C ADDRESS - 0x66 (W)	CS	ACK	CMD MSB - 0X71	ACK	CMD LSB - 0X54	ACK	MEM ADR	ACK
S	0 1 1 0 0 1 1 0			0 1 1 1 0 0 0 1		0 1 0 1 0 1 0 0		bit 7 bit 6 bit 5 bit 4 bit 3 bit 2 bit 1 bit 0	

DATA [0]	ACK		DATA [n]	ACK	CRC8	ACK	STOP
bit 7 bit 6 bit 5 bit 4 bit 3 bit 2 bit 1 bit 0		••	bit 7 bit 6 bit 5 bit 4 bit 3 bit 2 bit 1 bit 0		bit 7 bit 6 bit 5 bit 4 bit 3 bit 2 bit 1 bit 0		P

3.3 Data Definition

- There are 16-bit unsigned integers in the form of 2 bytes each.
- The MSB (most significant byte) comes first, then the LSB (least significant byte).
- After each 2 data bytes, a CRC byte („CRC8“) is sent to ensure that the data has been transferred correctly. This CRC8 is calculated from the 2 data bytes.

Property	**Value**
Width	8 bit
Polynomial	0x31 (x8 + x5 + x4 + 1)
XOR input	0xFF
Reflect input	False
Reflect output	False
XOR output	0x00

- If the data readout is cancelled (e.g., after „CO_2 average value“) then the rest of the data will not be read.
- Clock stretching is necessary to start the microcontroller and might occur before every ACK. I2C master clock stretching needs to be implemented according to the NXP NXP specs section 3.1.9. The boot-up time is < 500 ms.

3.4 Example for CRC8 Calculation:

```
#define CRC8_ONEWIRE_POLY 0x31
#define CRC8_ONEWIRE_START 0xff

static unsigned char i2cCalcCRC8 (unsigned char buf[], unsigned char from, unsigned char to)
{
  unsigned char crcVal = CRC8_ONEWIRE_START;
  unsigned char i = 0;
  unsigned char j = 0;
  unsigned char curval = 0;

  for (i = from; i < to; i ++)
  {
    int curVal = buf[i];
    for (j = 0; j < 8; j ++)
    {
      if (((crcVal ^ curVal) & 0x80) != 0) // If MSBs are not equal
      {
        crcVal = ((crcVal << 1) ^ CRC8_ONEWIRE_POLY);
      }
      else {
        crcVal = (crcVal << 1);
      }
      curVal = curVal << 1;
    }
  }
  return crcVal;
}
```

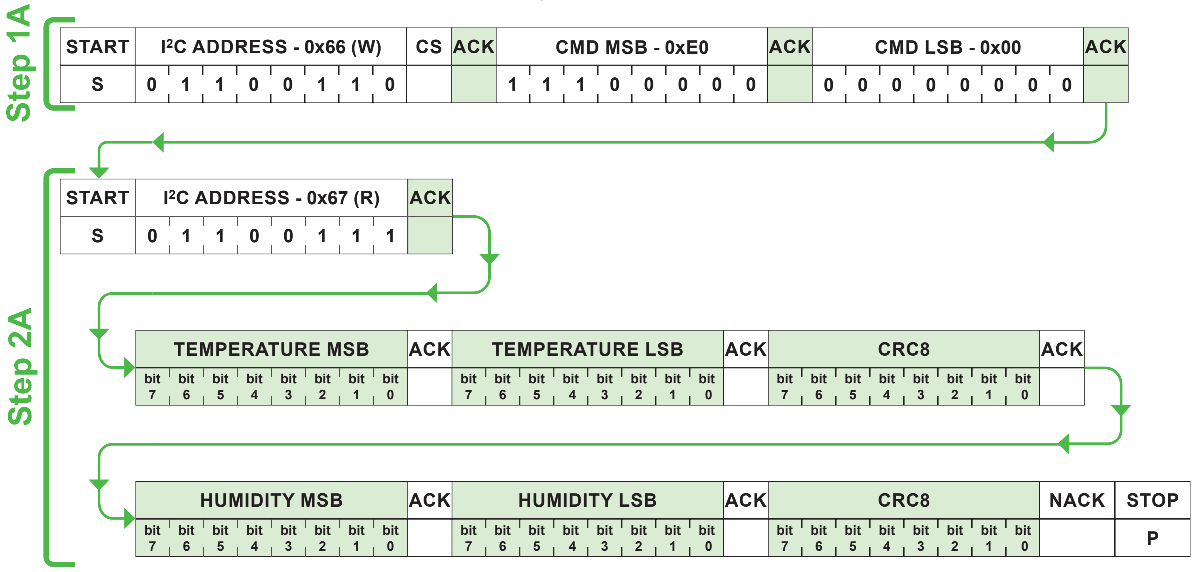
3.5 Communication Flow for Measurement Results

The green marked content comes from the module, other commands are sent by the master. First, the EE894 needs to be initialized on which two commands shall be read.

3.5.1 Reading Relative Humidity & Temperature - Command A: 0xE000

Step 1A:
Initialize command A or switch from command B to command A for reading the temperature and relative humidity data.

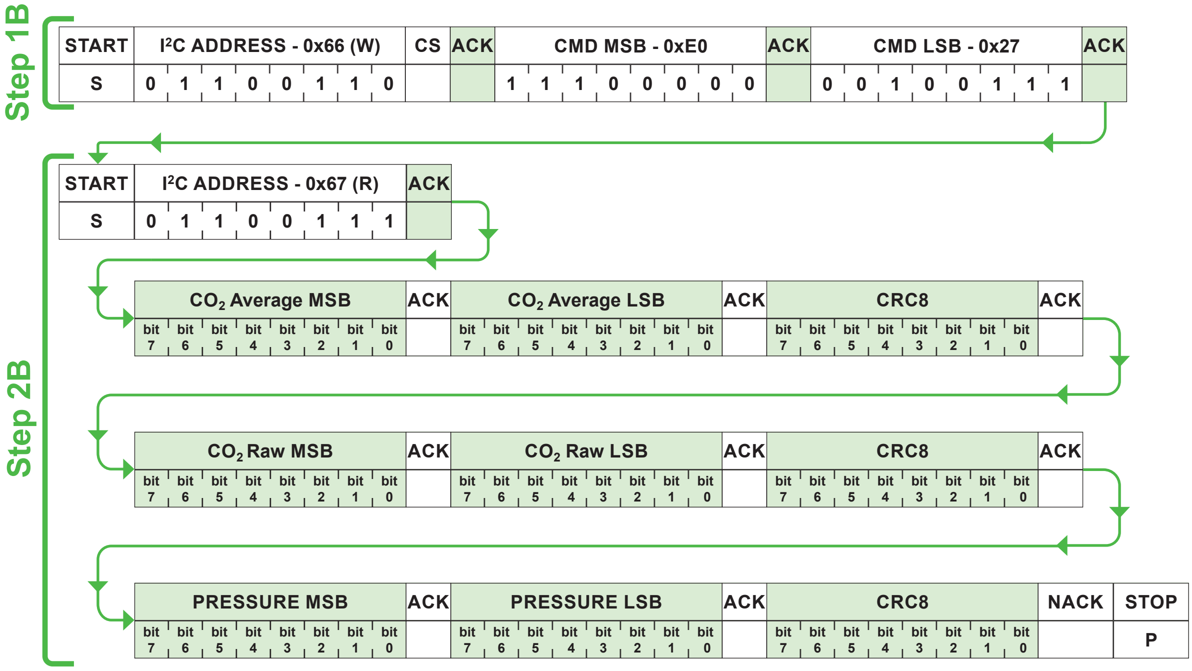
Step 2A:
Now the temperature and the relative humidity data can be read.



3.5.2 Reading CO_2 and ambient pressure - Command B: 0xE027

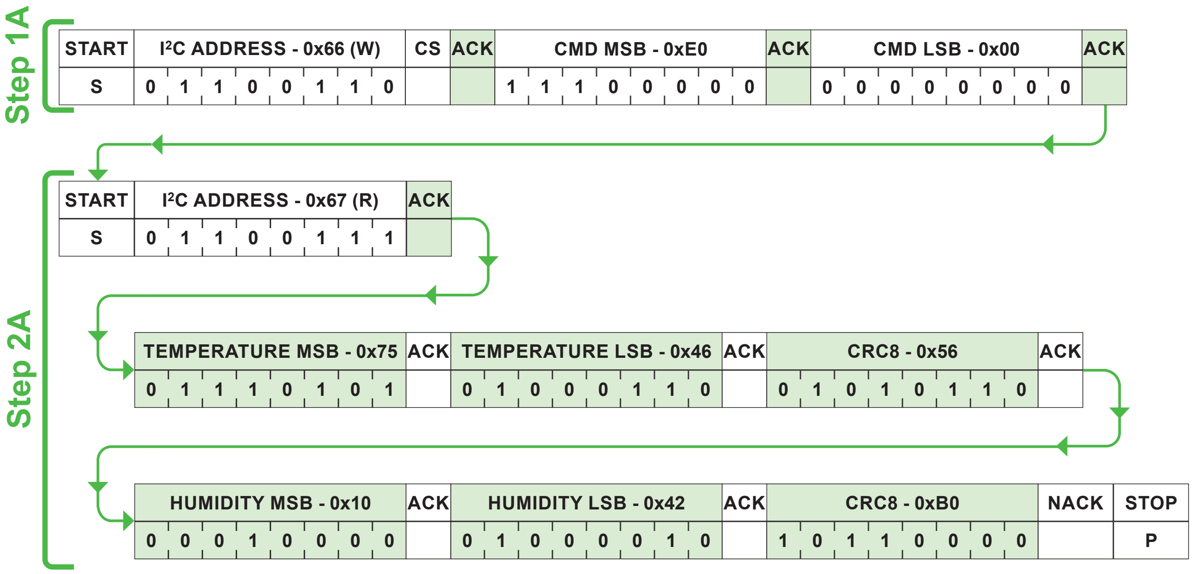
Step 1B:
Initialize command B or switch from command A to command B for reading the CO_2 and the ambient pressure data

Step 2B:
Now the CO_2 and ambient pressure data can be read:



3.6 Examples reading measurement results

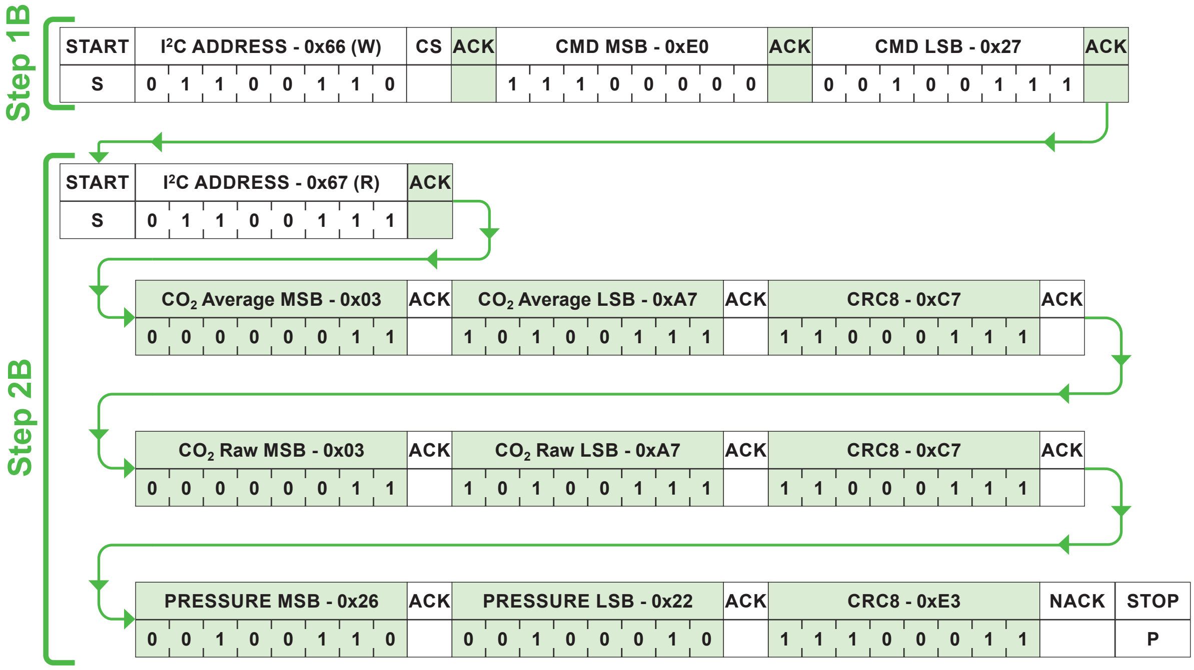
3.6.1 Reading Measurement Results RH/T - Command A: 0xE000



Calculation of measuring values

- Temperature: MSB 0x75 LSB 0x46 → 30022_{10} (30022/100 – 273.15) = 27.07 °C
- Relative humidity: MSB 0x10 LSB 0x42 → 4162_{10} (4162/100) = 41.62 %RH

3.6.2 Reading Measurement Results CO_2/p - Command B: 0xE027



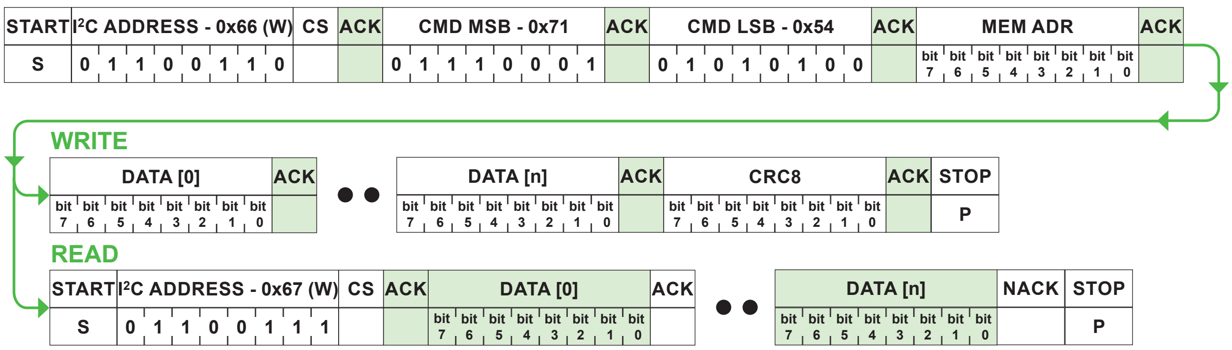
Calculation of measuring values

- CO_2 average: MSB 0x03 LSB 0xA7 → 935_{10} = 935 ppm
- CO_2 raw: MSB 0x03 LSB 0xA7 → 935_{10} = 935 ppm
- Pressure: MSB 0x26 LSB 0x22 → 9762_{10} (9762/10) = 976.2 mbar

4 Customer Memory Access

4.1 Main Command

- Structure of command for customer memory access: **0x7154**



The CRC8 checksum for writing into the customer memory is built out of the MEM ADR and the all DATA byte. This method for calculating the CRC8 works as protection of writing into the customer memory. As the module is processing the command after receive of the complete string, an incorrect CRC8 will also get confirmed by an ACK. Therefore it is recommended to read and compare the transmitted data.

4.2 Available Indexes

Index / MEM ADR	Function	Format	Unit	Comment
0 / 0x00	measurement time interval	2 byte	in 1/10 seconds	range 15 – 3600 seconds
1 / 0x01	CAM for relative humidity	4 (u)int16 values	in 1/100 %RH	• **offset** = int16 • **gain** = GainValue (uint16)/32768 • **lower limit** = (uint16) level of last "lower" adjustment point • **upper limit** = (uint16) level of last "upper" adjustment point
2 / 0x02	CAM for temperature	4 (u)int16 values	in 1/100 K	• **offset** = int16 • **gain** = GainValue (uint16)/32768 • **lower limit** = (uint16) level of last "lower" adjustment point • **upper limit** = (uint16) level of last "upper" adjustment point
3 / 0x03	CAM for pressure	4 (u)int16 values	in 1/10 mbar	• **offset** = int16 • **gain** = GainValue (unsigned int)/32768 • **lower limit** = (uint16) level of last "lower" adjustment point • **upper limit** = (uint16) level of last "upper" adjustment point
4 / 0x04	CAM for CO_2	4 (u)int16 values	in ppm	• **offset** = int16 • **gain** = GainValue (uint16)/32768 • **lower limit** = (uint16) level of last "lower" adjustment point • **upper limit** = (uint16 level of last "upper" adjustment point
5 / 0x05	date for CAM relative humidity	3 byte	day/month/year	DD / MM / YY
6 / 0x06	date for CAM temperature	3 byte	day/month/year	DD / MM / YY
7 / 0x07	date for CAM pressure	3 byte	day/month/year	DD / MM / YY
8 / 0x08	date for CAM CO_2	3 byte	day/month/year	DD / MM / YY
9 / 0x09	global date for CAM	3 byte	day/month/year	DD / MM / YY
10 / 0xA0	specific device name	16 byte	ASCII	all 16 byte must always be written, empty signs must be filled with 0x00

CAM...customer adjustment mode

4.3 Examples

• Change the measurement time interval to 20 seconds

Step	Message segment	Message Byte	Content
STEP 1	START	S	START condition
STEP 1	Address	0x66	I²C addresse (write)
STEP 1	Command MSB	0x71	MSB customer memory
STEP 1	Command LSB	0x54	LSB customer memory
STEP 1	Index	0x00	index for measurment time interval
STEP 2 WRITE	Data	0x00	measurment time interval MSB
STEP 2 WRITE		0xC8	measurment time interval LSB
STEP 2 WRITE	Checksum	0xB5	CRC
STEP 2 WRITE	STOP	P	STOP condition
STEP 2 READ	START	S	START condition
STEP 2 READ	Address	0x67	I²C adresse (read)
STEP 2 READ	Data	0x00	measurment time interval MSB
STEP 2 READ		0xC8	measurment time interval LSB
STEP 2 READ	STOP	P	STOP condition

- Add an pressure offset of -22.2 mbar @ reference 1013,2 mbar

	Message segment	Message Byte	Content
STEP 1	START	S	START condition
	Address	0x66	I²C addresse (write)
	Command MSB	0x71	MSB customer memory
	Command LSB	0x54	LSB customer memory
	Index	0x03	index for pressure
STEP 2 WRITE	Data	0xFF	offset MSB
		0x22	offset LSB
		0x80	gain MSB
		0x00	gain LSB
		0x00	lower limit MSB
		0x00	lower limit LSB
		0x27	upper limit MSB
		0x94	upper limit LSB
	Checksum	0xAF	CRC
	STOP	P	STOP condition
STEP 2 READ	START	S	START condition
	Address	0x67	I²C adresse (read)
	Data	0xFF	offset MSB
		0x22	offset LSB
		0x80	gain MSB
		0x00	gain LSB
		0x00	lower limit MSB
		0x00	lower limit LSB
		0x27	upper limit MSB
		0x94	upper limit LSB
	STOP	P	STOP condition

- Set date for CAM pressure to 24.12.2018

	Message segment	Message Byte	Content
STEP 1	START	S	START condition
	Address	0x66	I²C addresse (write)
	Command MSB	0x71	MSB customer memory
	Command LSB	0x54	LSB customer memory
	Index	0x07	index date for pressure
STEP 2 WRITE	Data	0x18	day (24)
		0x0C	month (12)
		0x12	year (18)
	Checksum	0x26	CRC
	STOP	P	STOP condition
STEP 2 READ	START	S	START condition
	Address	0x67	I²C adresse (read)
	Data	0x18	day (24)
		0x0C	month (12)
		0x12	year (18)
	STOP	P	STOP condition

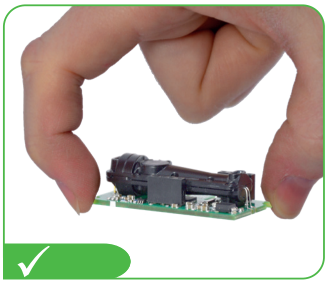
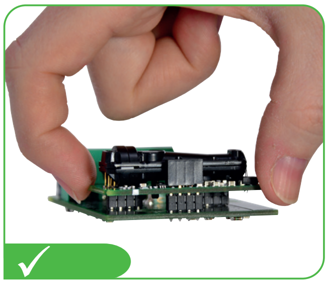
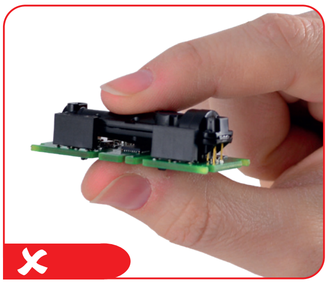
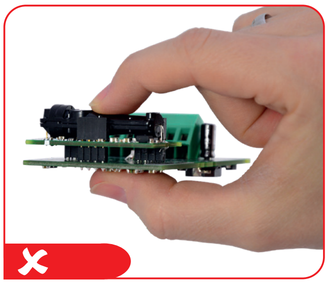
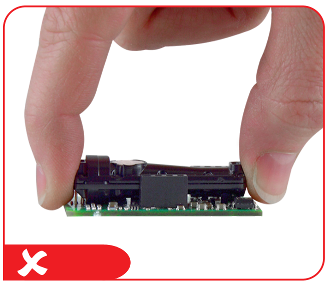
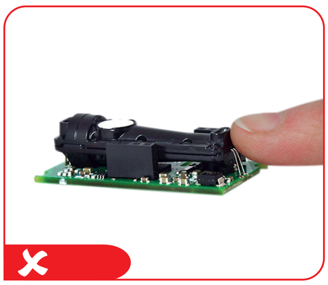
- Give the device the unique name: Best CO_2 sensor!

	Message segment	Message Byte	Content
STEP 1	START	S	START condition
	Address	0x66	I²C addresse (write)
	Command MSB	0x71	MSB customer memory
	Command LSB	0x54	LSB customer memory
	Index	0xA0	index specific device name
STEP 2 WRITE	Data	0x42	B in ASCII
		0x65	e in ASCII
		0x73	s in ASCII
		0x74	t in ASCII
		0x00	␣ in ASCII
		0x43	C in ASCII
		0x4F	O in ASCII
		0x32	2 in ASCII
		0x00	␣ in ASCII
		0x73	S in ASCII
		0x65	e in ASCII
		0x6E	n in ASCII
		0x73	s in ASCII
		0x6F	o in ASCII
		0x72	r in ASCII
		0x21	! in ASCII
	Checksum	0x40	CRC
	STOP	P	STOP condition
STEP 2 READ	START	S	START condition
	Address	0x67	I²C adresse (read)
	Data	0x42	B in ASCII
		0x65	e in ASCII
		0x73	s in ASCII
		0x74	t in ASCII
		0x00	␣ in ASCII
		0x43	C in ASCII
		0x4F	O in ASCII
		0x32	2 in ASCII
		0x00	␣ in ASCII
		0x73	S in ASCII
		0x65	e in ASCII
		0x6E	n in ASCII
		0x73	s in ASCII
		0x6F	o in ASCII
		0x72	r in ASCII
		0x21	! in ASCII
	STOP	P	STOP condition

5 Handling Instructions

- EE894 is an ESD sensitive device and shall be handled with corresponding precautions.
- EE894 and mainly the CO_2 sensing cell shall not be exposed to any mechanical stress during installation or operation. Mechanical stress on the sensing cell can lead to relevant measurement errors.
- For mounting EE894 with pins by soldering, the temperature at the EE894 module shall not exceed 60 °C (140 °F).

5.1 Handling and Mounting

6 Technical Data

Measured values

CO_2

Measurement principle	Dual wavelength NDIR (non-dispersive infrared technology)
Working range	0...2000 / 5000 / 10000 ppm
Accuracy at 25 °C and 1013 mbar [1)] (77 °F and 14.69 psi)	0...2000 ppm: < ± (50 ppm +2% of the measured value) 0...5000 ppm: < ± (50 ppm +3% of the measured value) 0...1% (0...10000 ppm): < ± (100 ppm +5% of the measured value)
Response time t_{90}	105 s with measured data averaging (smooth output) 60 s without measured data averaging
Temperature dependency	typ. ± (1 + CO_2 concentration [ppm] / 1000) ppm/°C (-20...45 °C) (-4...113 °F)
Pressure dependency	0.014 % of the measured value / mbar (ref. to 1013 mbar)
Calibration interval [2)]	>5 years
Sampling interval	from 15 s (factory setup) up to 1 h; user selectable

Relative humidity

Working range	0…95 % RH (non condensing)
Accuracy at 25 °C (77 °F)	typ. ± 3 % RH (20...80 % RH)

Pressure

Working range	700…1100 mbar (10.15...15.95 psi)
Accuracy at 25 °C (77 °F)	typ. ± 2 mbar (20…80 % RH)
Temperature dependency	± 0.015 mbar/K

Temperature

Working range	-40…60 °C (-40...140 °F)
Accuracy at 25 °C (77 °F)	typ. ± 0.5 °C (± 0.9 °F)

General

Digital interface	I²C
Supply voltage	4.75 - 7.5 V DC
Average current [3)] at 25 °C (77 °F) and 5 V supply	420 µA (at 1 h sampling interval) 3.2 mA (at 15 s sampling interval)
Electrical connection	contact pins and edge card socket
Working and storage conditions	-40...60 °C (-40...140 °F) 0...95 % RH (not condensating) 700...1100 mbar (10.15...15.95 psi)

1) With data averaging (smooth output) for averaging output.
2) Recommended under normal operating conditions in building automation.
3) The average current depends on the CO_2 sampling interval.

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