Sensor Description for

Sigrenea ultrasonic sensor

09-7224

UC4000-50K-B26-Y306056
Type-No: #306056

Firmware version: V1.2

1 General

1.1 About this Document

This document contains application notes for Sigrenea trash box sensors. In particular, the UC4000-50K-B26-Y306056 with the item number # 306056. It is intended as a supplementary document for certification processes for complex applications that require a deeper understanding of the internal workings of the ultrasonic sensors.

1.2 Revision History

Index	Author	Date	Changes
	C.Sertl	2017-04-25	Document creation (FW V1.0)
	T.Lolacher	2017-07-17	Checksum bit 6 always set to 1 (mandatory) Corrected cycle times, technical data and color assignment
	T.Lolacher	2017-11-07	Added example for response checksum calculation

1.3 Terms and definitions

Burst	Send signal to stimulate the ultrasonic transducer
Checksum	Check-Byte for data telegrams or parameter blocks
CPU	Central Processing Unit
HAL	Hardware Abstraction Layer
LIN	Local Interconnect Network
Master	The determining communication partner
MSB	Most Significant Bit
OP-Code	Operation Code
Slave	Communication partner with a minor role
Spike	Echo with too short duration for a valid measurement result

2 Sensor characteristics

2.1 Technical Data

Detection Range	250 …4000 mm
Blind zone	0 … 250 mm
Standard target	100 mm x 100 mm
Transducer frequency	approx. 75 kHz
Power on delay	< 25 ms
Power supply	3,3… 5,5V
Power consumption	<= 70mA at 3,3V
Interface	Rx/Tx LIN
Resolution	16 mm (1 LSB)
Temperature compensation	Yes
Storage temperature range	-40…+85°C
Operating temperature range	-25…+70°C
Connecting cable	
Protection	IP67

2.2 The color assignment of the connecting cable

The sensor is designed for a supply voltage in the range of 3,3 – 5,5 volts. The colour assignment of the connecting cable:

Brown	V_{cc} (3,3…5,5 V)
Blue	Ground (0 V)
Black	Communication (LIN phys.)
Green	UART Rx (3,3V)
White	UART Tx (3,3V)

3 Ultrasonic measurement system

The measurement system of ultrasonic sensors is based on the known echo runtime principle. The piezoelectric ceramic is in this case used alternately as transmitter and receiver. A fundamental problem results from the relatively high damping of ultrasound in air. This requires a strong excitation of the piezoelectric ceramic and a high gain receiver electronics. For stable and reliable measurement results, a highly reactive firmware is still required, which adaptively adjusts the receiver characteristics in real time during the measurement, filter out noise and qualify potential measurement results.

3.1 Description of the different measurement profiles

3.1.1 Profiles with output of a single echo

The sensor outputs the target distance normalized to 8bit and a check-byte which contains the acknowledge Bit and the checksum of the answer.
Output data * 1,6 = distance in cm
The user can set the number of measurement cycles to be performed with a single trigger

3.1.1.1 Measurement Profile “A” – OP-Code 0xFE

Measurement Profile for short range detection

Sensitivity:	minimum
Detection range:	250...3500 mm (with reference target: plate 100x100mm)
Cycle time / Time out	Cycles x 50 ms + 10 ms
Sound cone width:	see 3.2

3.1.1.2 Measurement Profile “B” – OP-Code 0xFD

Measurement Profile for middle range detection

Sensitivity:	medium
Detection range:	250...4000 mm (with reference target: plate 100x100mm)
Cycle time / Time out	Cycles x 50 ms + 10 ms
Sound cone width:	see 3.2

3.1.1.3 Measurement Profile “C” – OP-Code 0xFC

Measurement Profile for far range detection

Sensitivity:	maximum
Detection range:	250...4000 mm (with reference target: plate 100x100mm)
Cycle time / Time out	Cycles x 50 ms + 10 ms
Sound cone width:	see 3.2

3.1.1.4 User specific Measurement Profile “A” - OP-Code 0x37

The user can define a user specific profile

The settings for burst length, gain and driver current can be determined by the user.
Each parameter can be set by its own LIN protocol which stores the value in the sensor.

Sensitivity:	user defined
Max detection range	up to 4 meters (with reference target: plate 100x100mm)
Cycle time / Time out	Cycles x 50 ms + 10 ms

For possible Parameter settings see Annex A1 and A2

3.2 *Sound cones*

3.2.1 For Output of one echo, Profil A to C (target 100 x 100mm (Radial))

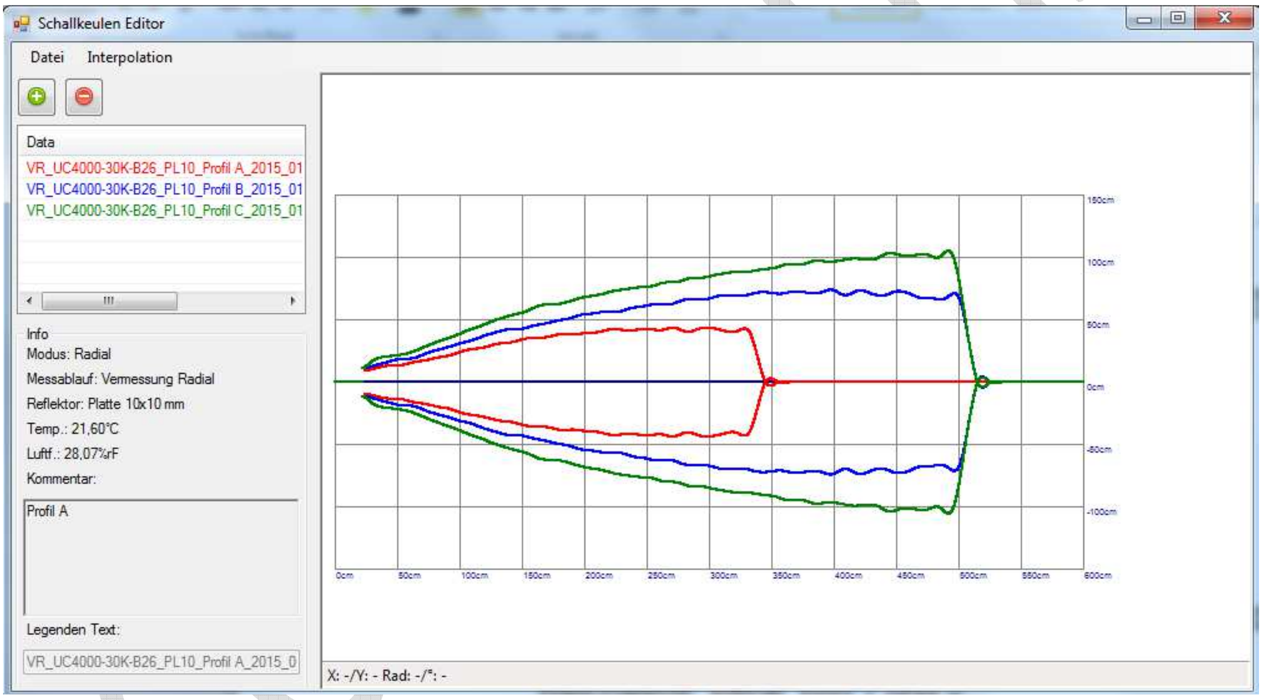


Figure 1 Sound cone for profile A to C with 100 x 100 mm target (Radial)

3.2.2 For Output of one echo, Profil A to C (round target 25mm (Radial))

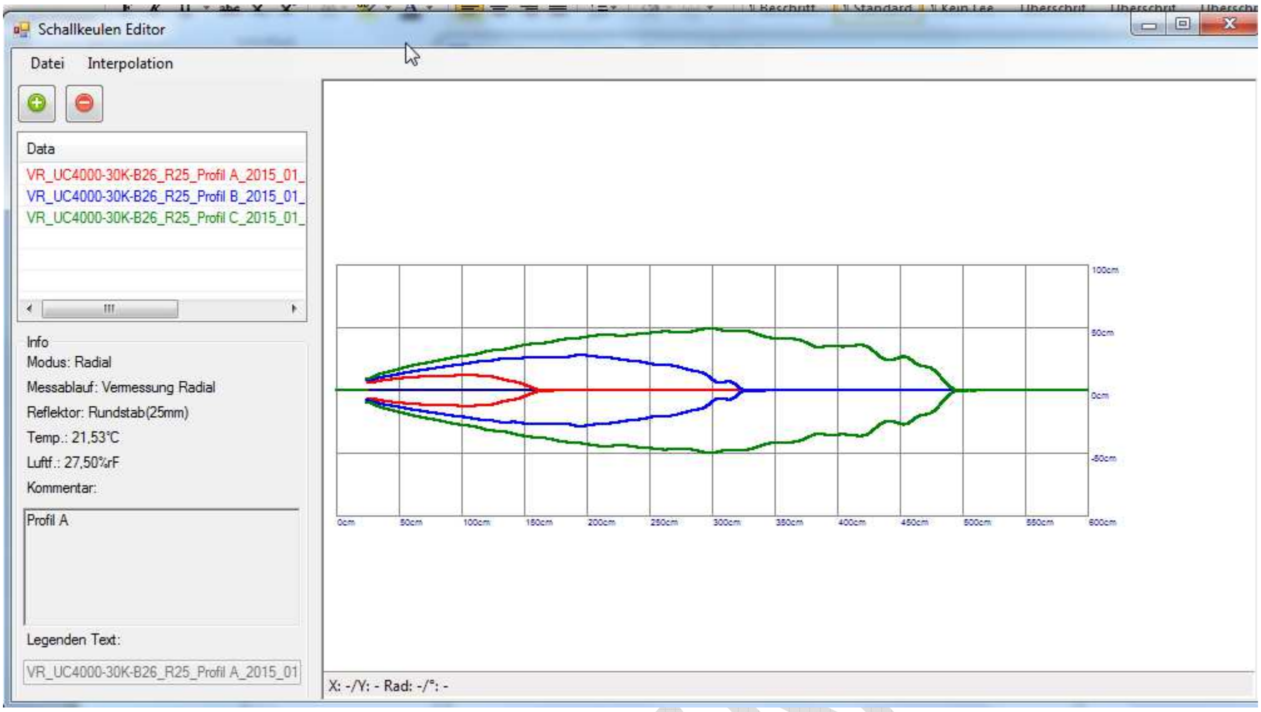


Figure 3 Sound cone for profile A to C with round target 25 mm (Radial)

3.3 Sequence of a measuring operation

The Sequence of a measurement cycle consists basically of three states.
This would include:

- Communication Master → Sensor (Request)
- Measurement cycle
- Communication Slave → Master (Response)

Depending on the measured profile, the time between the request message and response message vary widely. The timeout periods are described in detail in the individual measuring profiles.

3.3.1 End of the Measurement

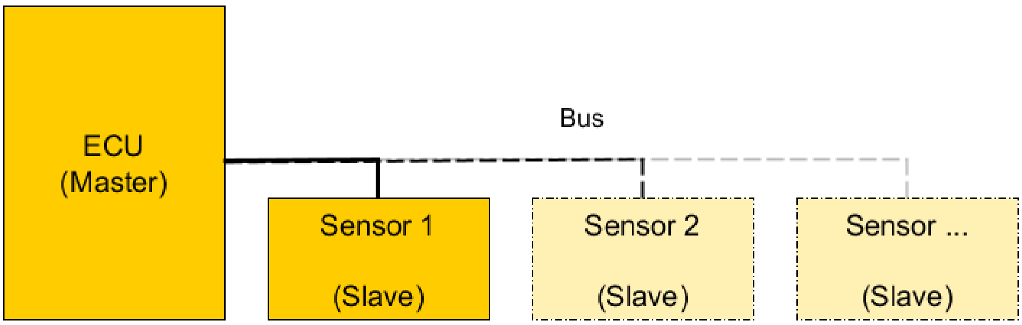
The measurement stops after the set echo detection time. Then, the sensor evaluates the echoes (filtering) and returns the result as a measurement value.

3.3.2 Echo evaluation

The sensor outputs the echo which is most likely the echo from the filling material. Disturbances like Spikes and echoes with low amplitude are rejected.
The return value is the measured distance in centimeter.
In case there is no echo detected the return value is 00_{hex}.
In case there is an echo in the blind zone the return value is 01_{hex}
In case there is an echo detected > 4 m the return value is $0xFF_{hex}$
If the acknowledge flag in the Checkbyte is set, the return value is the measurement value.

4 Communication

The communication of the sensor is realized by a point-to-point or point-to-multipoint connection which is based on a physical LIN bus interface. The sensor works as slave. The communication is described in detail below.



Communication:

→ Data rate: 19.2 kBaud/s
→ Bit coding: compatible with LIN standard
→ Bit format: UART bit stream with 1 start bit, 8 data bits and 1 stop bit

4.1 The master - slave principle

During the communication process, the external controller takes the master role. The sensor is in this communication always the slave. A role reversal will never happen, not even in exceptional situations (starting, error recovery, etc.)

The master controls each communication structure by using a telegram he sent to the slave.

4.2 The communication process

The communication is based on the principle of polling. The master sends a complete telegram to the sensor (slave) and then waits for its response.

4.3 Communication error

Communication errors are explicitly reported by the slave to the master (error message) or implicitly recognized by the master (timeout, checksum). The response sole responsibility of the master and is application dependent.

4.4 Definition of the communication protocol

4.4.1 Object Structure

The communication objects (OP) objects of the sensors are constructed as follows:

- a unique 8-bit ID
- Optional additional, subsequent byte with a meaning that is derived from the ID

The surgical objects have no length byte or structure description. They are identified by their ID on the master and slave side, and are therefore by definition in terms of their structure (e.g. "16 bit unsigned value") and their attributes (e.g. "read-only") known.

With an 8-bit ID can be addressed 256 different objects. The ID 255 are reserved: 255 for an extension identifier. Thus the object directory and thus the protocol for future use can be extended if required.

4.4.2 Object groups

Die OP-Object IDs can be grouped as follows:

- Measurement profiles – messages to start ultrasonic measurement with different parameters
- Sensor system – messages for sensor functionality (reset to manufacturing setup)
- Manufacturing – messages only used in the manufacturing
- Parameters – messages only used for parameter access in the customized measurement profile.

4.5 Telegram overview

4.5.1 Telegram structure

Request messages (from master to sensor) consist of the following components:

- 1 Byte SYNCH:
  - Bit 7...4 = Synch
  - Bit 3 Access Read / Write (mandatory)
  - Bit 2..0 Address bits 0...7 Default = 7
- 1 Byte application OP-code
- n Byte DATA
- 1 Byte Error-Flag and Checksum

Response messages (from the sensor to the master) consist of the following components:

- n byte response data
- 1 byte Error-Flag and Checksum (mandatory)

In the current implementation data strings are available with a length of 2 to 19 bytes.

4.5.2 Telegram groups

The Interface defines the communication structure immediately following a response message for each request message. This can be a positive response or a negative response to the request. The messages are grouped as follows:

- Read requests are 4 bytes long
- Positive answers to read requests are of different lengths (e.g. sensor ID)
- Negative responses to read requests are 2 bytes long
- Write requests have different length (e.g. parameters)
- Positive responses to Write requests are 2 bytes long
- Negative answers to write requests are 2 bytes long

The respective message frame is recognized by a gap of length 2 bytes on the transmission link. Multi-byte telegrams are terminated by an timeout with an length of two byte.

4.5.3 Calculating the telegram checksum

The telegram checksum provides data integrity protection for data transmission from master to the sensor and from sensor to the master. Block signals are used. All bytes in a telegram are XORed bit-by-bit. The resulting checksum byte is compressed from 8 to 6 bits in accordance with the conversion formula below and added to the CHECK byte on the transmitter. The receiver reverses the procedure. A start value of 0x52 is used for checksum calculation. This start value is used for the XORing with the first byte.

Compression from 8 to 6 bytes is performed as follows:

$D5_6 = D7_8 \text{ xor } D5_8 \text{ xor } D3_8 \text{ xor } D1_8$
$D4_6 = D6_8 \text{ xor } D4_8 \text{ xor } D2_8 \text{ xor } D0_8$
$D3_6 = D7_8 \text{ xor } D6_8$
$D2_6 = D5_8 \text{ xor } D4_8$
$D1_6 = D3_8 \text{ xor } D2_8$
$D0_6 = D1_8 \text{ xor } D0_8$

NOTE:
When calculating the checksum in the response telegram of the sensor bit 7 of check byte has to be taken into the checksum calculation. After calculating the checksum bit 6 of check byte must be set.

Response Checksum calculation example:

Sensor response:	23 D1		
D1 as binary:	1101 0001		
Extract bit 7 from checksum:	1000 0000	=>	hex: 80
Calculate checksum:	52 xor 23 xor 80	=	F1
F1 as binary:	1111 0001		
6Bit checksum:	0001 0001		
Set bit 6 to 1 (mandatory):	0101 0001		
Set bit 7 to its origin value:	1101 0001	=>	hex: D1

4.5.4 Structure of the CHECK byte

7	6	543210
0	1	0x..
ACK/NACK	Man-da-tory	Checksum

If bit 7 = 1 → ACK (the byte is a valid object value)
= 0 → NACK (the byte is a value from the error code table 0)

Bit 6 = 1 → is mandatory,
Reason: Checksum must not be 0xA. => otherwise problems if more sensors are in Multi-plex or Synch Mode, because checksum of 0xA. Could be interpreted as Synch-Byte

4.5.5 Structure of the SYNC byte

7654	3	210
0xA	1/0	0x..
SYNC	R/W	S-Adr.

Bit 0…2: Sensor address – The default factory device address is 0x7.
Possible Values: 1....7
Bit 3: Read/Write – Flag
Read (R): 1 Write (W): 0
Bit 4…7: Sync sequence 0xA is mandatory
Telegram example 1: Read request – measurement profile A
A read request for the sensor address looks like as follows:

A) Master sends 4 Byte request to sensor:

7654	3	210
0xA	R	0x..
SYNC	R/W	S-Adr.

7…0
0xFE
OP-code

7…0
0x..
Data

7…0
0x..
CHECK

Data: number of measurement cycles
0xFF = invalid value
0XFE = 1 cycle
0xFD = 2 cycles

B1) Either: The sensor sends 2 bytes data response to the master:

7…0
0x..
Object data

7	6	543210
1	1	0x..
ACK/NACK Flag	Man-da-tory	Checksum

Object data *1,6 = target distance [cm]

B2) Or: The sensor sends 2 Byte error code to the master:

7…0
0x..
Response code

7	6	543210
0	1	0x..
ACK/NACK Flag	Man-da-tory	Checksum

The cause of the failed read attempt is included in the NAK message. The distinction whether it is a data value or error code is defined by the checksum.
Error code table: see 0

4.5.6 Telegram example 2: Write request - set Sensor address

A write request for the setting of the sensor address looks like as follows:

A) Master sends 4 Byte request to sensor:

7654	3	210	7…0	7…0	7…0
0xA	W	0x1	0x35	0x01	0x..
SYNC	R/W	S-Adr.	OP-code	Data	CHECK

B1) Either: The sensor sends 1 byte data response + Checksum to the master:

7…0	7	6	543210
0x01	1	1	0x..
Data	ACK/NACK Flag	Man-da-tory	Checksum

B2) Or: The sensor sends 1 byte error code + Checksum to the master:

7…0	7	6	543210
0x..	0	1	0x..
Response code	ACK/NACK Flag	Man-da-tory	Checksum

The distinction whether it is a data value or response code is distinguished by the ACK/NACK Flag.
Error code table: see 0

4.6 Object Directory

The following object directory contains all internal system and application specific communication objects together with the relevant accessibility and user data. The real messages on the transmission path result directly therefrom by applying the following rules:

- The first byte of each request message is composed of 4 synchronization bits, 1 R/W bit and the 3 bit sensor address.
- The access bit (READ: 1/WRITE: 0) occurs only in the request telegram
- The sensor address occurs only in the request telegram.
- The second byte of each request message contains the Object ID (OP Code)
- With the third byte of each request message the user data are included.
- The last byte of each read/write request message contains the check byte.
- The reply-bit (ACK: 1/NAK: 0) is part of the CHECK bytes. It is meaningful only in the response telegram. In the request message, this bit is always 0

The response telegrams are usually two bytes long and are typically structured as follows:

- The first byte contains the data, and the second byte is the CHECK-byte.

- In some cases, more than one byte of user data is transmitted. In this case the last byte is the CHECK-byte.

4.6.1 Summary of all possible Object Codes

See Annex A5

4.6.2 Error codes

The table below contains all the possible response codes

Code	Description
FF_h	Response OK / No error
01_h	Checksum Error
02_h	Telegram timeout
03_h	Telegram underflow
04_h	Telegram overflow
05_h	Parameter Error
06_h	Session Error
07_h	Transmission Error
08_h	EEPROM Error
09_h	OP-Code Error
$0A_h$	OP-Object is read only
$0B_h$	Temperature Error
$0C_h$	
$0D_h$	

5 Overview of the communication messages

The messages are classified into the following groups:

- ♦ Measurement profiles – messages to start a measurement profile
- ♦ Sensor service – messages for sensor information (e.g. FW-Version)

The classification has no technical background, but is only to obtain a better overview.

The illustration of the request and response messages in the following chapters are always listed for the positive case of error-free communication. Because all faulty communications are handled in the same way. (see chapter 0)

5.1 Measurement Profiles

The messages in this group are for the start of a measurement initiated by the master.

5.1.1 OP-Code: Read Temperature - 0xFF

```
ObjID: ObjectID_Temperature == 0xFF
```

4 Bytes Master → Sensor

7654	3	210	7…0	7…0	7…0
0xA	R	0x..	0xFF	0x..	0x..
SYNC	R/W	S-Adr.	OP-code	Data	CHECK

Data: don't care (0xFF is recommended due to lowest current consumption)

2 Bytes Master ← Sensor

7…0	7…0
0x..	0x..
Data	CHECK

Data[signed integer] = Temperatur [°C]

5.1.2 OP-Code: Read target distance with Measurement Profile "A" - 0xFE

```
ObjID: ObjectID_Profile_A == 0xFE
```

4 Bytes Master → Sensor

7654	3	210	7…0	7…0	7…0
0xA	R	0x..	0xFE	0x..	0x..
SYNC	R/W	S-Adr.	OP-code	Data	CHECK

Data: contains the number of measurement cycle to be performed.
(0xFE = 1 cycle; 0xFD = 2 cycles;…)

2 Bytes Master ← Sensor

7…0	7…0
0x..	0x..
Data	CHECK

Data * 1,6 = Distance [cm]

If more than 1 cycle is performed the output is an average of all measurement cycles

5.1.3 OP-Code: Read target distance with Measurement Profile “B” - 0xFD

```
ObjID: ObjectID_PROFILE_B == 0xFD
```

4 Bytes Master → Sensor

7654	3	210	7…0	7…0	7…0
0xA	R	0x..	0xFD	0x..	0x..
SYNC	R/W	S-Adr.	OP-code	Data	CHECK

Data: contains the number of measurement cycle to be performed. (0xFE = 1 cycle; 0xFD = 2 cycles;…)

2 Bytes Master ← Sensor

7…0	7…0
0x..	0x..
Data	CHECK

Data * 1,6 = Distance [cm]

If more than 1 cycle is performed the output is an average of all measurement cycles

5.1.4 OP-Code: Read target distance with Measurement Profile "C" - 0xFC

```
ObjID: ObjectID_PROFILE_C == 0xFC
```

4 Bytes Master → Sensor

7654	3	210	7…0	7…0	7…0
0xA	R	0x..	0xFC	0x..	0x..
SYNC	R/W	S-Adr.	OP-code	Data	CHECK

Data: contains the number of measurement cycle to be performed. (0xFE = 1 cycle; 0xFD = 2 cycles;…)

2 Bytes Master ← Sensor

7…0	7…0
0x..	0x..
Data	CHECK

Data * 1,6 = Distance [cm]

If more than 1 cycle is performed the output is an average of all measurement cycles

5.1.5 OP-Code: Read target distance with User specific measurement profile "A" - 0x37

```
ObjID: ObjectID_Profile_User_A == 0x37
```

4 Bytes Master → Sensor

7654	3	210	7…0	7…0	7…0
0xA	R	0x..	0x37	0x..	0x..
SYNC	R/W	S-Adr.	OP-code	Data	CHECK

Data: contains the number of measurement cycle to be performed. (0xFE = 1 cycle; 0xFD = 2 cycles;…)

2 Bytes Master ← Sensor

7…0	7…0
0x..	0x..
Data	CHECK

Data * 1,6 = Distance [cm]

If more than 1 cycle is performed the output is an average of all measurement cycles

5.1.6 OP-Code: Read/Write Sensor address - 0x35

`ObjID: ObjectID_Sensor_Address == 0x35`

5.1.6.1 Read sensor address

If more than 1 sensor is connected this command can be used to get to know which sensor addresse are connected

4 Bytes Master → Sensor

7654	3	210	7…0	7…0	7…0
0xA	R	0x..	0x35	0xFF	0x..
SYNC	R/W	S-Adr.	OP-code	Data	CHECK

2 Bytes Master ← Sensor

7…0	7…0
0x..	0x..
Sensor Address	CHECK

5.1.6.2 Set sensor address

5 Bytes Master → Sensor

7654	3	210	7…0	7…0	7…0
0xA	W	0x..	0x35	0x..	0x..
SYNC	R/W	S-Adr.	OP-code	Data	CHECK

Data = new sensor address

2 Bytes Master ← Sensor

7…0	7…0
0x..	0x..
Data	CHECK

Data = new sensor address

5.1.6.3 Read the sensor address with the Cast command

If the device address for a sensor device is not known, it can be read out by a Cast command. The device address of this command is 0.
In this case only one sensor can be connected

4 Bytes Master → Sensor

7654	3	210	7…0	7…0	7…0
0xA	R	0x0	0x00	0x00	0x43
SYNC	R/W	S-Adr.	OP-code	Data	CHECK

2 Bytes Master ← Sensor

7…0	7…0
0x..	0x..
Sensor Address	CHECK

5.1.7 OP-Code: Read Sensor hardware / software version - 0x34

`ObjID: ObjectID_HW_FW_Version == 0x34`

4 Bytes Master → Sensor

7654	3	210	7…0	7…0	7…0
0xA	R	0x..	0x34	0xFF	0x..
SYNC	R/W	S-Adr.	OP-code	Data	CHECK

Data: content not relevant but transmission mandatory
any value from 0x00 to0xFF allowed
Recommended value: 0xFF (lowest current consumption)

19 Bytes Master ← Sensor

7…0	7…0	7…0	7…0
0x..	0x..	0x.. '\0'	0x..
Data[0]	Data[1]	Data[n]	CHECK

n = 17
Data Bytes = the characters of the version are transmitted in ASCII format
The string is terminated by zero value '\0'

Example for Hardware-Version V0.1 and Software-Version V1.0

Byte	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hex	48	57	3A	56	30	2E	31	20	53	57	3A	56	31	2E	30	30	30	00	Check
ASCII	H	W	:	V	0	.	1	␣	S	W	:	V	1	.	0	0	0	0	..

For example: 'H','W',':','V','0','.','1',' ','S','W',':','V','1','.','0','0','0','\0'

5.2 Parameter

With the following OP-Codes the user can set the parameters for burst periods, amplifier gain, and driver current which is used at <<user specific measurement profil A>> (OP-Code 0x37)

5.2.1 OP-Code: Number of burst cycles - 0x23 (User profile "A")

```
ObjID: ObjectID_Burst_Len_A == 0x23
```

5.2.1.1 Read number of burst periods

4 Bytes Master → Sensor

7654	3	210	7…0	7…0	7…0
0xA	R	0x..	0x23	0x..	0x..
SYNC	R/W	S-Adr.	OP-code	Data	CHECK

Data: any value possible
Recommended 0xFF (lowest current consumption)

2 Bytes Master ← Sensor

7…0	7…0
0x..	0x..
Data	CHECK

Data: the sensor responds with the user specific number of burst periods.
For possible values see A1

5.2.1.2 Write number of burst periods

4 Bytes Master → Sensor

7654	3	210	7…0	7…0	7…0
0xA	W	0x..	0x23	0x..	0x..
SYNC	R/W	S-Adr.	OP-code	Data	CHECK

Data: number of burst periods for user Profil A. For possible values see A1

2 Bytes Master ← Sensor

7…0	7…0
0x..	0x..
Data	CHECK

Data: Sensor response with written number of burst periods (Must be the same as in the transmit command Master → Sensor)

5.2.2 OP-Code: Amplifier Gain - 0x22 (User profile “A”)

```
ObjID: ObjectID_Ampl_Gain_A == 0x22
```

5.2.2.1 Read Amplifier Gain value

4 Bytes Master → Sensor

7654	3	210	7…0	7…0	7…0
0xA	R	0x..	0x22	0x..	0x..
SYNC	R/W	S-Adr.	OP-code	Data	CHECK

Data: content not relevant but transmission mandatory
any value from 0x00 to0xFF allowed
Recommended value: 0xFF (lowest current consumption)

2 Bytes Master ← Sensor

7…0	7…0
0x..	0x..
Data	CHECK

Data: the sensor responds with the user specific amplifier gain. For possible values see A1

5.2.2.2 Write Amplifier Gain value

4 Bytes Master → Sensor

7654	3	210	7…0	7…0	7…0
0xA	W	0x..	0x22	0x..	0x..
SYNC	R/W	S-Adr.	OP-code	Data	CHECK

Data: for possible values see A1

2 Bytes Master ← Sensor

7…0	7…0
0x..	0x..
Data	CHECK

Data: Sensor response with written amplifier gain (Must be the same as in the transmit command Master → Sensor)

5.2.3 OP-Code: Transducer Current - 0x21 (User profile "A")

`ObjID: ObjectID_Current_A == 0x21`

5.2.3.1 Read Transducer Current value

4 Bytes Master → Sensor

7654	3	210	7…0	7…0	7…0
0xA	R	0x..	0x21	0x..	0x..
SYNC	R/W	S-Adr.	OP-code	Data	CHECK

Data: content not relevant but transmission mandatory
any value from 0x00 to0xFF allowed
Recommended value: 0xFF (lowest current consumption)

2 Bytes Master ← Sensor

7…0	7…0
0x..	0x..
Data	CHECK

Data: the sensor responds with the user specific driver current. For possible values see A1

5.2.3.2 Write Transducer Current value

4 Bytes Master → Sensor

7654	3	210	7…0	7…0	7…0
0xA	W	0x..	0x21	0x..	0x..
SYNC	R/W	S-Adr.	OP-code	Data	CHECK

Data: for possible values see A1

2 Bytes Master ← Sensor

7…0	7…0
0x..	0x..
Data	CHECK

Data: Sensor response with written driver current (Must be the same as in the transmit command Master → Sensor)

5.2.3.3 Temperature Compensation ON/OFF

7654	3	210	7…0	7…0	7…0
0xA	W	0x..	0x0A	0x..	0x..
SYNC	R/W	S-Adr.	OP-code	Data	CHECK

Data: 0xFF = Temperature Compensation ON
0x00 = Temperature Compensation OFF

5.3 Sensor Service

The messages in this group are required to initiate the tasks concerning the sensor information.

5.3.1 OP-Code: Sensor Hardware / Software Version - 0x34

`ObjID: ObjectID_HW_FW_Version == 0x34`

4 Bytes Master → Sensor

7654	3	210	7…0	7…0	7…0
0xA	R	0x..	0x34	0xFF	0x..
SYNC	R/W	S-Adr.	OP-code	Data	CHECK

Data: content not relevant but transmission mandatory
any value from 0x00 to0xFF allowed
Recommended value: 0xFF (lowest current consumption)

19 Bytes Master ← Sensor

7…0	7…0	7…0	7…0
0x..	0x..	0x.. '\0'	0x..
Data[0]	Data[1]	Data[n]	CHECK

n = 17
Data Bytes = the characters of the version are transmitted in ASCII format
The string is terminated by zero value '\0'

Example for Hardware-Version V0.1 and Software-Version V1.0

Byte	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hex	48	57	3A	56	30	2E	31	20	53	57	3A	56	31	2E	30	30	30	00	Check
ASCII	H	W	:	V	0	.	1	␣	S	W	:	V	1	.	0	0	0	0	..

For example: 'H','W',':','V','0','.','1',' ','S','W',':','V','1','.','0','0','0','\0'
Hardware information: HW:V0.1
Software information: SW:V1.0 (test version: Tx.xxx
released version: Vx.xxx)

5.3.2 OP-Code: Serial number - 0x33

```
ObjID: ObjectID_Serial_Nr == 0x33
```

4 Bytes Master → Sensor

7654	3	210	7…0	7…0	7…0
0xA	R	0x..	0x33	0xFF	0x..
SYNC	R/W	S-Adr.	OP-code	Data	CHECK

15 Bytes Master ← Sensor

7…0	7…0	7…0	7…0
0x..	0x..	0x..	0x..
Data[0]	Data[1]	Data[n]	CHECK

n = 13
Data Bytes = the characters of the Serial Number are transmitted in ASCII format

Example for Serial number 40000016900001

Byte	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Hex	34	30	30	30	30	30	31	36	39	30	30	30	30	31	Check
ASCII	4	0	0	0	0	0	1	6	9	0	0	0	0	1	..

Annex:

A1: Data code for user specific parameters

Burstperiods	Data	Ampl Gain [dB]	Data	Drive Current [mA]	Data
4	0x00	56,5	0x00	160	0x00
8	0x01	57	0x01	165	0x01
12	0x02	57,5	0x02	171	0x02
16	0x03	58	0x03	176	0x03
20	0x04	58,5	0x04	181	0x04
24	0x05	59	0x05	186	0x05
28	0x06	59,5	0x06	192	0x06
32	0x07	60	0x07	197	0x07
36	0x08	60,5	0x08	203	0x08
40	0x09	61	0x09	208	0x09
44	0x0A	61,5	0x0A	213	0x0A
48	0x0B	62	0x0B	219	0x0B
52	0x0C	62,5	0x0C	224	0x0C
56	0x0D	63	0x0D	229	0x0D
60	0x0E	63,5	0x0E	235	0x0E
64	0x0F	64	0x0F	240	0x0F
		64,5	0x10	245	0x10
		65	0x11	251	0x11
		65,5	0x12	256	0x12
		66	0x13	261	0x13
		66,5	0x14	267	0x14
		67	0x15	272	0x15
		67,5	0x16	277	0x16
		68	0x17	283	0x17
		68,5	0x18	288	0x18
		69	0x19	293	0x19
		69,5	0x1A	299	0x1A
		70	0x1B	304	0x1B
		70,5	0x1C	309	0x1C
		71	0x1D	315	0x1D
		71,5	0x1E	320	0x1E
		72	0x1F	325	0x1F
		72,5	0x20	331	0x20
		73	0x21	336	0x21
		73,5	0x22	341	0x22
		74	0x23	347	0x23
		74,5	0x24	352	0x24
		75	0x25	357	0x25
		75,5	0x26	363	0x26
		76	0x27	368	0x27
		76,5	0x28	373	0x28
		77	0x29	379	0x29
		77,5	0x2A	384	0x2A
		78	0x2B	389	0x2B
		78,5	0x2C	395	0x2C
		79	0x2D	400	0x2D
		79,5	0x2E	405	0x2E
		80	0x2F	411	0x2F

Burstperiods	Data	Ampl Gain [dB]	Data	Drive Current [mA]	Data
		80,5	0x30	416	0x30
		81	0x31	421	0x31
		81,5	0x32	427	0x32
		82	0x33	432	0x33
		82,5	0x34	437	0x34
		83	0x35	443	0x35
		83,5	0x36	448	0x36
		84	0x37	453	0x37
		84,5	0x38	459	0x38
		85	0x39	464	0x39
		85,5	0x3A	469	0x3A
		86	0x3B	475	0x3B
		86,5	0x3C	480	0x3C
		87	0x3D	485	0x3D
		87,5	0x3E	491	0x3E
		88	0x3F	496	0x3F

A2: Sound-cones for user specific measurement profile

The user specific measurement profile is defined by three parameters. These parameters Burst (B), Gain (G) and Current (C) have an influence to the response curve of the sensor. Some measurement settings and its detection range are listed in the Figures below. The reference target is defined as plan plate with 100mm.

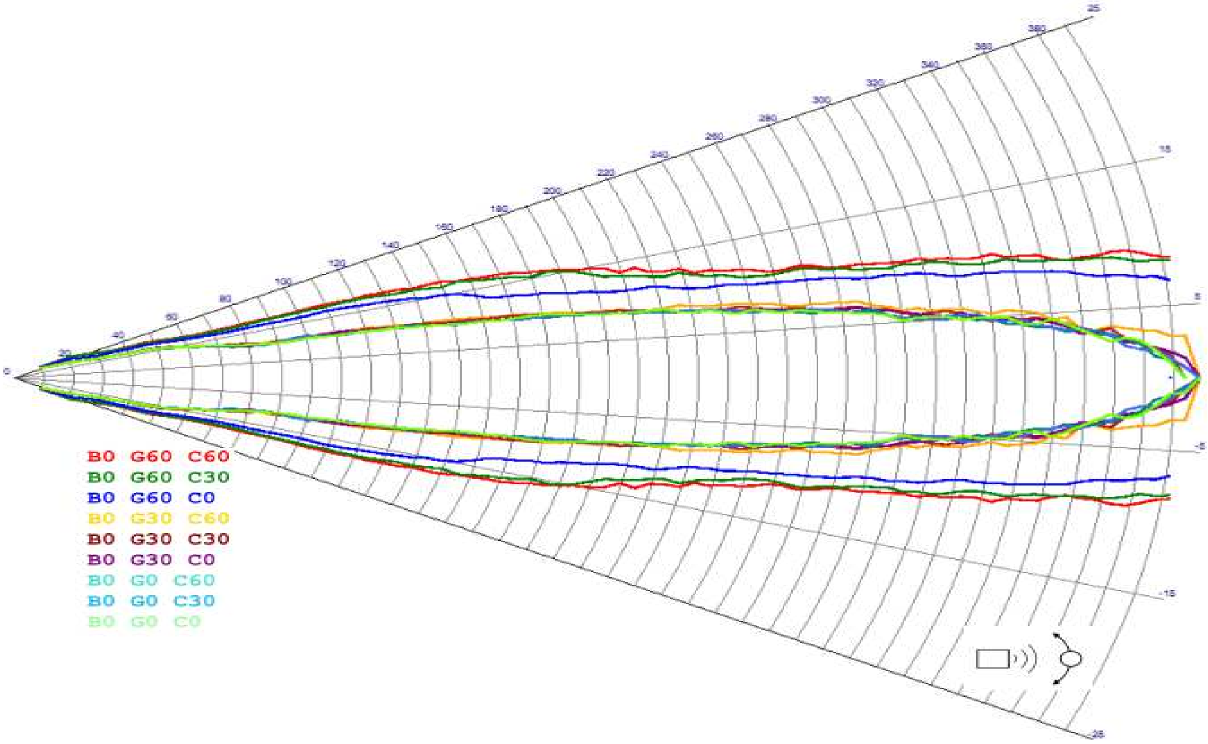


Figure 2 Detection range with Burst value 0

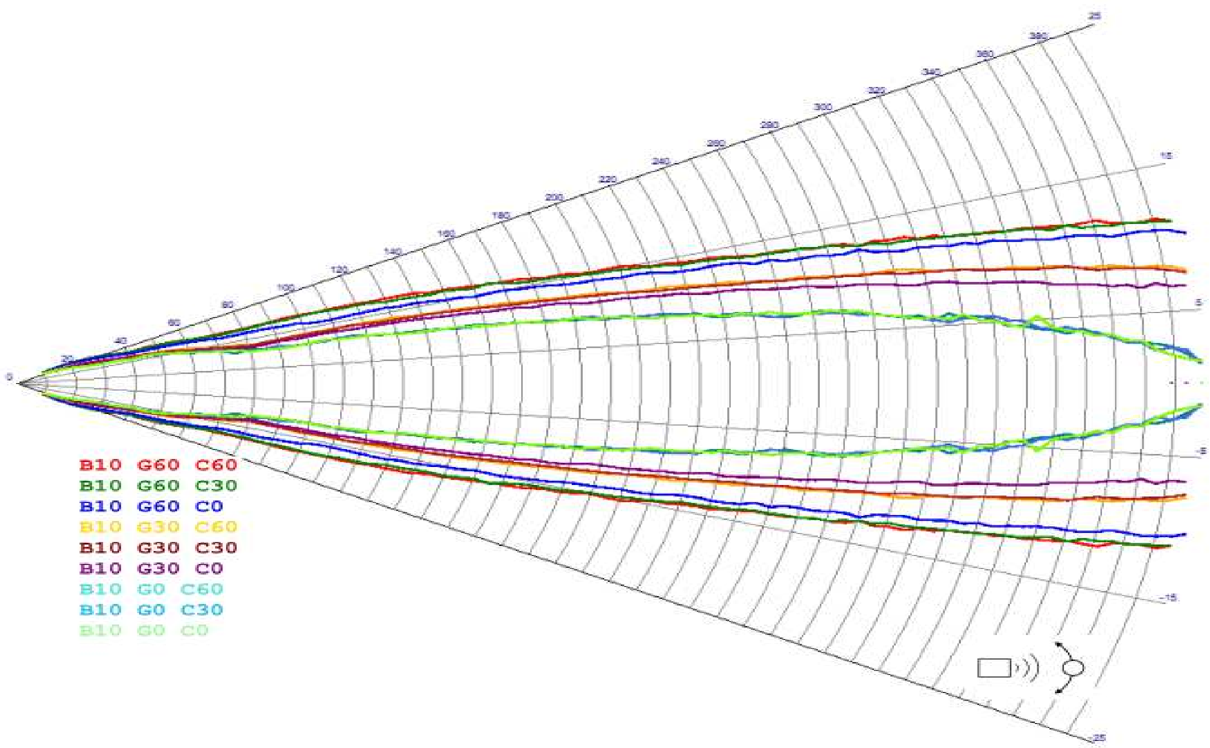


Figure 3 Detection range with Burst value 10

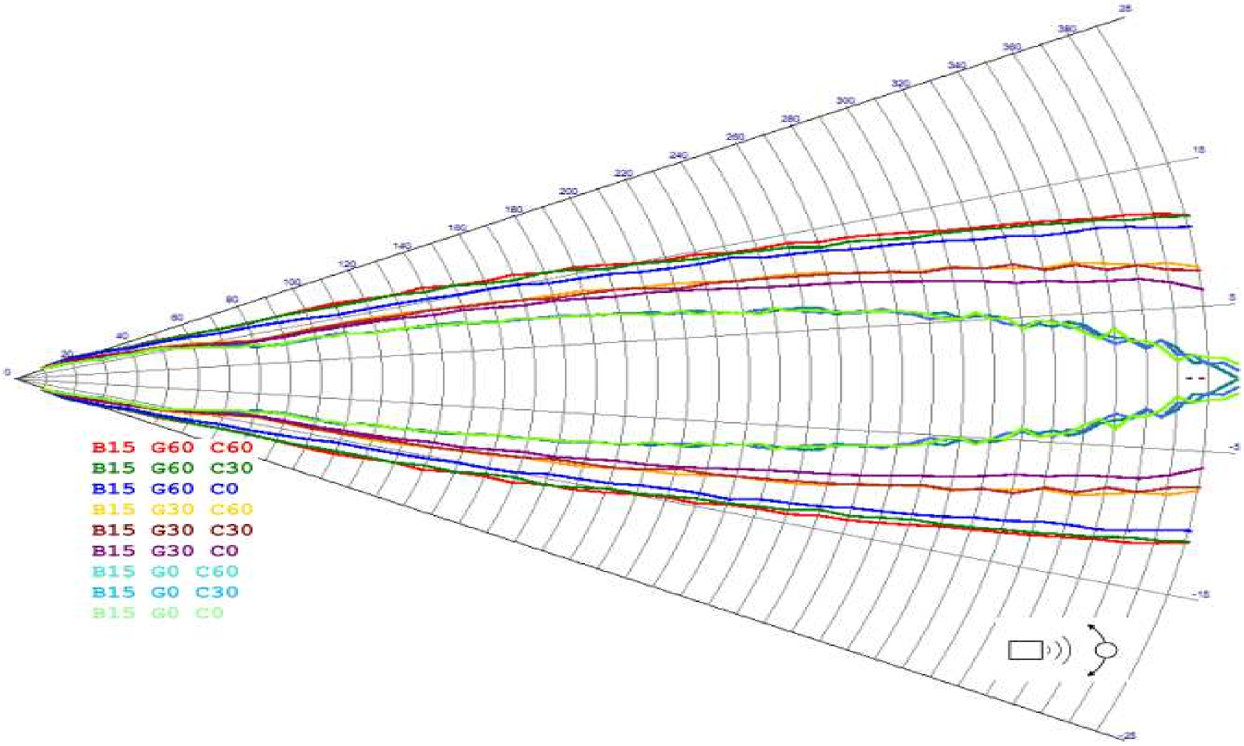


Figure 4 Detection range with Burst value 15

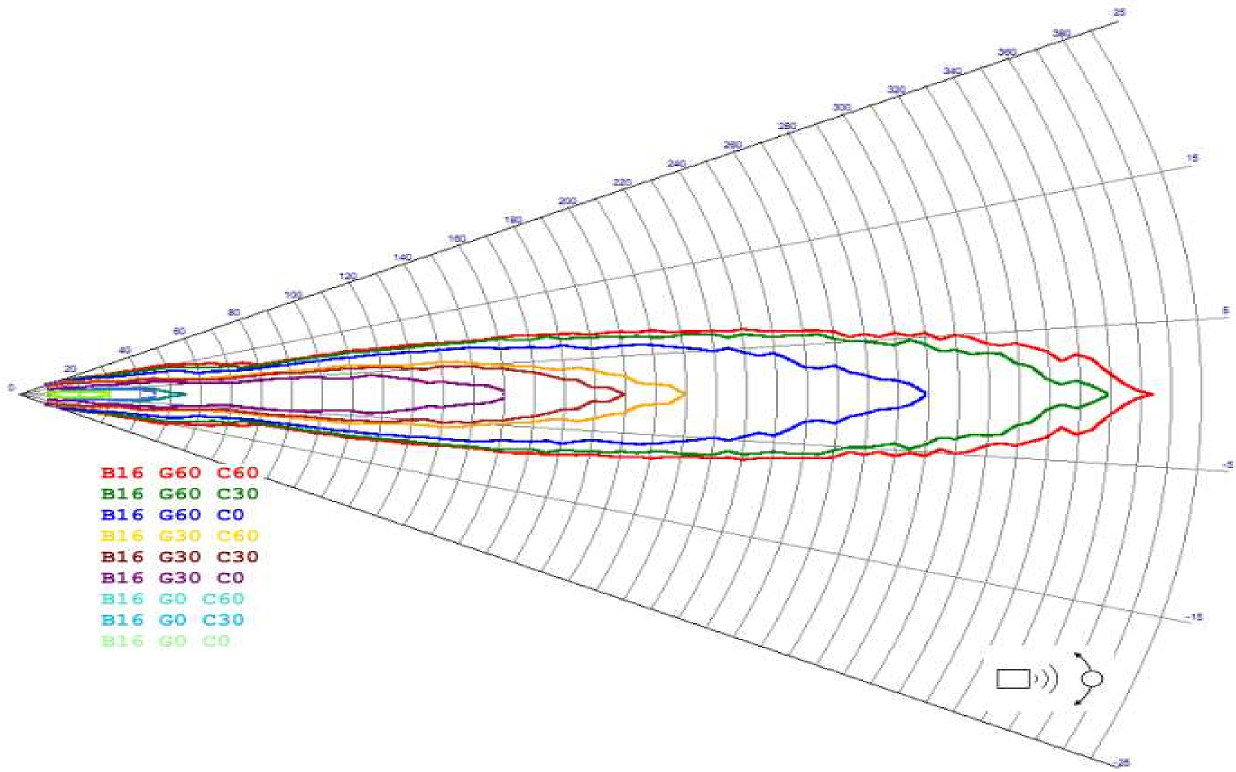


Figure 5 Detection range with short distance burst settings: Burst value 16

A3 Listing of the Operation Codes (OP-Codes)

Transmit Bytes of the Master								Response bytes from sensor			
								Data		Check Byte 4)	
OP-Object ID	SYNC 4567	R/W 3	Adr 012	OP-Code 1 Byte	Data n Bytes	Check Byte	Description	n bytes	discription	ACK Bit 7	Bit 5...0 Check sum
Measurement Profiles											
Temperature	0xA	R	..	0xFF	1 byte: number of measurement cycles	y	Request a temperature measurement	1	Temperature [°C]	1	y
Profile_A	0xA	R	..	0xFE	1 byte: number of measurement cycles	y	Request a distance meas-urement	1	data * 1,6 = distance [cm]	1	y
Profile_B	0xA	R	..	0xFD	1 byte: number of measurement cycles	y	Request a distance meas-urement	1	data * 1,6 = distance [cm]	1	y
Profile_C	0xA	R	..	0xFC	1 byte: number of measurement cycles	y	Request a distance meas-urement	1	data * 1,6 = distance [cm]	1	y
USER_Pro-file_A	0xA	R	..	0x37	1 byte: number of measurement cycles	y	Request a distance meas-urement with user parame-ters for burst, gain and driver current	1	data * 1,6 = distance [cm]	1	y
Sensor System											
SENSOR_ Address	0xA	R/W	..	0x35	Read: 1 Byte: 0xFF Write: 1Byte sensor address	y	Get or set the sensor addr. 1)	1	Sensor Address (1...7)	1	y
GetSen-sor_Address Cast command 3)	0xA	R	0	00	0x00	y	Get Sensor address (not possible with more than one sensor on the bus)	1	Sensor address	1	y
HW_FW_ Version	0xA	R	..	0x34	1 byte: 0xFF	y	Get the sensor hardware and firmware version	17	ASCII Code e.g. HW:V0.1 SW: TV1.0	1	y
Get_Serial_ Nr	0xA	R	..	0x33	1 byte: 0xFF	y	Get the serial number	14	ASCII Code 14-digit serial number	1	y