SONOTEC

Sensor for Air Bubble Detection in Flexible Tubes

SONOCHECK

Protocol of Serial Interface

- CONFIDENTIAL -

Manufacturer:	SONOTEC Ultraschallsensorik Halle GmbH
Model:	Sensor for air bubble detection
Type:	ABD05 / ABD06 / ABD07 / ABD08

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Contents

1 Notes on Operating Manual and Safety

1.1 General

This description is a **confidential** part of the operating manual. It contains information for serial protocol of the air bubble detectors series ABD05 / ABD06 / ABD07 / ABD08. It must therefore be read and understood in its entirety before operation begins and before any subsequent steps are undertaken.

1.2 Symbols Used

Information about hazards or special information is indicated in the following way:

	**Caution!** This symbol warns of potential damage.

	**Note** This symbol gives tips or draws attention to distinctive features.

1.3 Safety Information

	**Caution!** Read and follow carefully all safety instructions in the manual for the air bubble detector series ABD05/ ABD06/ ABD07/ ABD08.

Any use other than the intended is forbidden. SONOTEC Ultraschallsensorik Halle GmbH accepts no liability for damage, including that to third parties, caused by improper use.

2 Specification of Input / Output of Bubble Sensor

2.1 Electrical Specifications

Serial inputs / outputs are TTL compatible signals.

Logic Level	Input	Output
L	0 to 0.5 V	0 to 0.5 V
H	4.5 to 5 V	4.5 to 5 V

Table 1: Specification of Input / Output for Serial Interface

Caution!

The output is specified as a TTL compatible signal, it cannot drive more than approx. 2 mA. Protect the digital input and output from overvoltage.

Note

Sensors series ABD06 provide an independent powered switch signal additionally. Following this output will not be considered.

2.2 Settings of UART

If the input / output is used as serial port the interface is set as following:

- Asynchronous UART
- 1 start bit, 1 stop bit, no parity, no handshaking
- Baud rate: 115.200 kBaud

2.3 Modes for Interface

2.3.1 Overview

There are different modes for interface:

Mode	Specification Output	Specification Input	Remarks	Available
0	Switching output	Serial input for controlling or for generating bubble test	Default setting	V1.30 … V1.43
1	Serial output, short protocol for measuring the bubble size	Serial input for controlling or for generating bubble test		V1.30 … V1.43
2	Serial output, long protocol for service and diagnosis	Serial input for controlling or for generating bubble test		V1.30 … V1.43
3	Serial output, dialog mode	Serial input for controlling or for generating bubble test	Service only	V1.30 … V1.43
4	Switching output	Digital test signal to generate bubble test, L active		V1.40 … V1.43
5	Switching output	Digital test signal to generate bubble test, H active		V1.40 … V1.43
6	Pulse Width Modulation	Digital test signal to generate bubble test, L active		V1.40 … V1.43
7	Pulse Width Modulation	Digital test signal to generate bubble test, H active		V1.40 ... V1.43
8	Pulse Width Modulation	Serial input for controlling or for generating bubble test		V1.40 ... V1.43
9	Switching output	Converted to a toggling output FAIL		V1.42 … V1.43
10	Switching output	Input for external restart of sensor		V1.43

Table 2: Specification of Input and Output

The switching output (Mode 0) is default. The serial output has to be activated by a serial command (see chapter 3). For applications with Fail-Safe-Security requirements the output is intended to be configured as serial interface (Mode 1 or 2) or as PWM (Mode 6 ... 8).

2.3.2 Mode 0

Mode 0 is used for easy detection of bubbles.

The output is specified as TTL. The assignment to an event can be configured by parameters.

Default settings are:

Assignment	Output
Liquid is measured, no bubbles, no fault	L
Bubbles have occurred	H
Any measuring alarm (e.g. no tubing)	H
Device fault	H

Table 3: Default Setting of Switching Output

The input is connected to the serial port. This way the sensor reacts to all serial commands (see chapter 3). To check the sensor the serial command **`CmdBubbleTest`** should be sent periodically.

2.3.3 Mode 1

Mode 1 (Normal) is used for measuring the bubble size.

A sequence of 3 bytes is emitted which provides information on the condition of the sensor as well as on further measured values.

The output cycle will be repeated after each 1 ms. The start pattern and the check sum guarantees that the signal sequence is interpreted accurately. The superior control unit interprets any lack of serial signals as fault status.

Time	No.	Function
T = 0 µs	Byte 0	**Start Pattern:** FEH
T = 200 µs	Byte 1	**Bubble Size** Range: 00H to F0H In case of any device fault: bubble size is set to value = F1H
T = 400 µs	Byte 2	**CRC** Bit 0 to 5: CRC over byte 1 Bit 6 to 7: 0 Start value: FEH Polynomial: D4H
T = 1 ms + 0 µs	Byte 0	(Next) Start pattern (FEH)
...	...	...

Table 4: Protocol for Mode 1, measuring mode = short protocol (for details to data see notes in chapter 4)

The input is connected to serial port. This way the sensor reacts to all serial commands (see chapter 3).

To check the sensor the serial command **`CmdBubbleTest`** should be sent periodically.

2.3.4 Mode 2

Mode 2 is used for service only, for measuring the bubble size and internal measuring values. A sequence of 5 bytes is emitted which provides information about the condition of the sensor as well as further measured values.

The output cycle will be repeated after each 1 ms. The start pattern and the check sum guarantees that the signal sequence is interpreted accurately. The superior control unit interprets any lack of serial signals as fault status.

The bubble sensor gives out an array of 16 bytes with internal data in a defined order. These values serve debugging, checking the measurement or indicating codes in case of faults. These data have not to be observed in the final application in the machine.

Time	No.	Function
T = 0 µs	Byte 0	**Start Pattern:** FFH
T = 200 µs	Byte 1	**Bubble Size** Range: 00H to F0H In case of any device fault: bubble size is set to value = F1H
T = 400 µs	Byte 2	**Pointer** (of data array) Bit 0 to 3: range 0 to 15, point to 1 of the 16 bytes of data array Bit 4 to 6: 0 Bit 7: = bit 7 of data The pointer will be incremented after each cycle of serial output.
T = 600 µs	Byte 3	**Data** Pointed byte of data array with measured values bit 7 = 0, moved to pointer, bit 7
T = 800 µs	Byte 4	**CRC** Bit 0 to 5: CRC over byte 1 to 3 Bit 6 to 7: 0 Start value: FFH Polynomial: D4H
T = 1ms + 0 µs	Byte 0	(Next) Start pattern (FFH)
...	...	...

Table 5: Protocol for Mode 2, service mode = long protocol (for details to data see notes in chapter 4)

The input is connected to serial port. This way the sensor reacts to all serial commands (see chapter 3). To check the sensor the serial command **`CmdBubbleTest`** should be sent periodically.

2.3.5 Mode 3

Mode 3 is used for service only, especially for measuring values and debugging.

The sensor operates in dialog mode. Every serial output has to be triggered by a serial command. For details to commands see chapter 3.

	**Caution!** This mode is **not suitable** for continues bubble detection.

2.3.6 Mode 4 and Mode 5

Mode 4 and 5 are used for easy detection of bubbles.

The output is specified as TTL. The assignment to an event can be configured by parameters.

Default settings are:

Assignment	Output
Liquid is measured, no bubbles, no fault	L
Bubbles have occurred	H
Any measuring alarm (e.g. no tubing)	H
Device fault	H

Table 6: Default Setting of Switching Output

The input is connected as digital test signal to initiate a bubble test. Holding active level on input the amplitude of the sent pulse will be decreased (approx. to 8 dB). The received signal is reduced adequately and is interpreted as a bubble occurrence.

Mode 4: Logic Level	Mode 5: Logic Level	Function of Input
H	**L**	Bubble test active
L	**H**	Normal operation

Table 7: Bubble Test Using Digital Test Signal

For checking the sensor the test should be repeated periodically.

Immediate after “Power on” the input is connected to serial interface for a short time (approx. 1 s). Then the serial interface is switched off and the input is configured as digital test signal.

If you want to change mode or settings, you have to send the appropriate commands shortly after “Power on”.

Note (Not for sensors series ABD06)

The ABD Monitor with USB Data Converter Type 007 supports the special timing to change settings for sensors series ABD05 / ABD07 / ABD08.

2.3.7 Mode 6 and Mode 7

Mode 6 and 7 are used for output bubble size or bubble events using pulse-width-modulated signal.

The output is specified as TTL.

Output rate of PWM is 1kHz. Width of modulation is assigned to bubble events or bubble size. This can be configured freely by parameters.

Event	Modulation
No bubble	20 %
Small bubbles below threshold	21 … 79 %
Dangerous bubbles	80 %
Any measuring alarm (e.g. no tubing)	80 %
Device Fault	90 %

Table 8: Default Setting of PWM output

The input is connected as digital test signal to initiate a bubble test. Holding active level on input the amplitude of the sent pulse will be decreased (approx. to 8 dB). The received signal is reduced adequately and is interpreted as a bubble occurrence.

Mode 6: Logic Level	Mode 7: Logic Level	Function of Input
H	**L**	Bubble test active
L	**H**	Normal operation

Table 9: Bubble Test Using Digital Test Signal

For checking the sensor the test should be repeated periodically.

Immediate after “Power on” the input is connected to serial interface for a short time (approx. 1 s). Then the serial interface is switched off and the input is configured as digital test signal.

If you want to change mode or settings, you have to send the appropriate commands shortly after “Power on”.

Note (Not for sensors series ABD06)

The ABD Monitor with USB Data Converter Type 007 supports the special timing to change settings for sensors series ABD05 / ABD07 / ABD08.

2.3.8 Mode 8

Mode 8 is used for output bubble assize or bubble events using pulse-width-modulated signal.

The output is specified as TTL.

Output rate of PWM is 1 kHz. Width of modulation is assigned to bubble events or bubble size. This can be configured freely by parameters.

Event	Modulation
No bubble	20 %
Small bubbles below threshold	21 … 79 %
Dangerous bubbles	80 %
Any measuring alarm (e.g. no tubing)	80 %
Device Fault	90 %

Table 10: Default Setting of PWM output

The input is connected to serial port. This way the sensor reacts to all serial commands (see chapter 3). To check the sensor the serial command **`CmdBubbleTest`** should be sent periodically.

2.3.9 Mode 9

Mode 9 is used for easy detection of bubbles. The input is reconfigured shortly after power on as an additional output FAIL to signalize the state of sensor.

The output AIR is specified as TTL. The assignment to an event can be configured by parameters.

The output FAIL is specified as open collector.

Default settings are:

Assignment	Output AIR	Output FAIL
Liquid is measured, no bubbles, no fault	L	Toggling signal, Period 1 s, 50 % modulation
Bubbles have occurred	H	
Any measuring alarm (e.g. no tubing)	H	
Device Fault	H	Static signal L

Table 11: Default Setting of Switching Outputs

Feature of external bubble simulation test is not available.

Immediate after “Power on” the input is connected to serial interface for a short time (approx. 1 s). Then the input is reconfigured into an output.

If you want to change mode or settings, you have to send the appropriate commands shortly after “Power on”.

Note (Not for sensors series ABD06)

The ABD Monitor with USB Data Converter Type 007 supports the special timing to change settings for sensors series ABD05 / ABD07 / ABD08.

2.3.10 Mode 10

Mode 10 is used for easy detection of bubbles.

The output is specified as TTL. The assignment to an event can be configured by parameters.

Default settings are:

Assignment	Output
Liquid is measured, no bubbles, no fault	L
Bubbles have occurred	H
Any measuring alarm (e.g. no tubing)	H
Device fault	H

Table 12: Default Setting of Switching Output

The input is connected as digital test signal to initiate a full restart of sensor. Holding level L on input releases a restart of sensor. Sensor is forced to restart and a full self-test will be performed, including test of internal watchdog and outputs. Mode 10 is especially applied for continues operation about more than 24h.

Feature of external bubble simulation test is not available.

Logic Level	Function of Input
H	Normal operation
L	Restart is forced

Table 13: Sensor Restart Using Input

Period of level has to be held active can be configured by parameters.

Immediate after “Power on” the input is connected to serial interface for a short time (approx. 1 s). Then the serial interface is switched off and the input is configured as digital test signal.

If you want to change mode or settings, you have to send the appropriate commands shortly after “Power on”.

Note (Not for sensors series ABD06)

The ABD Monitor with USB Data Converter Type 007 supports the special timing to change settings for sensors series ABD05 / ABD07 / ABD08.

3 Serial Commands for Controlling Sensor

3.1 Overview to Commands

The frame of commands has the following structure:

Byte	Function
0	Start pattern: F1H
1/2	H/L byte with count of bytes in the frame *(up to now: count is 5 or 6 bytes only)*
3	**Code for Commands in Mode 0 / 1 / 2 / 8** (see notes below) **`CmdSetLED`** 31H **`CmdSetSerialMode`** 32H **`CmdRestart`** 16H **`CmdBubbleTest`** 33H **Additional Codes for Commands in Mode 3** (dialog mode only). **`CmdPing`** 29H **`CmdGetIdent`** 25H **`CmdGetValues`** 23H Further commands are available. But they are used only in case of service by SONOTEC, do not use them without authorization. For details contact our service staff please.
4 to n-1	Data, if necessary
n	**CRC** Bit 0 to 5: CRC over byte 1 to n-1 Bit 6 to 7: 0 Start value: F1H Polynomial: D4H

Table 14: Serial Commands for Controlling the Sensor

3.2 Command CmdSetLED

The bubble sensors can control integrated LEDs automatically. The LEDs can also be set via serial commands (remote control).

Frame	F1H / 00H / 06H / 31H / Data / CRC	
Data	Bit 0	Set green LED (0: off or 1: on)
	Bit 1	Set red LED (0: off or 1: on)
	Bit 2	Set blue LED (0: off or 1: on)
	Bit 3	= 0: LEDs are controlled by serial command from the machine = 1: LEDs are set depend on bubbles (default)
	Bit 4 to 7	Not in use, do not care

Table 15: Frame and Meaning of Data for Setting LED

Note

There are no integrated LEDs in some sensors series, e.g. ABD06. It is not useful to apply command `CmdSetLED`. Otherwise command is ignored.

The blue LED is available in sensor series ABD05 only.

3.3 Command CmdSetSerialMode

For security requirements e.g. it is recommended to configure the interface of the bubble sensor for serial output. This could be realized with the superior control unit in the following way:

Software Version V1.30

Frame	F1H / 00H / 06H / 32H / Data / CRC	
Data	Bit 0 to 3	Not in use, don't care
	Bit 7|6|5|4	Serial mode = **0000**: switch signal output (default, L = liquid or H = air or bubbles) = **0001**: standard protocol (default) = **0011**: service protocol = **01x1**: serial dialog mode = **1xxx**: digital test input = **x**: 0 or 1, don't care

Table 16: Frame and Meaning of Data for Setting Serial Mode, Version V1.30

Software Version V1.40 or higher

Frame	F1H / 00H / 06H / 32H / Data / CRC	
Data	0 to 10	Serial Mode 0 … 10

Table 17: Frame and Meaning of Data for Setting Serial Mode, Version V1.40 or higher

Note

Depending on software version not all serial modes are available, see Table 2. If a serial mode is activated does not implemented, sensor switches to serial mode 0.

3.4 Command CmdBubbleTest

The superior control unit can perform a bubble test to check the functionality of the bubble sensor. For a given count of cycles the sent pulse will be triggered with reduced amplitude. This way the received amplitude is reduced accordingly and the bubble sensor will also react in case of bubbles.

Frame	**F1H / 00H / 06H / 33H / Data / CRC**	
Data	0 to 250	Count of cycles with reduced sent energy. Each cycle takes 0.2 ms

Table 18: Frame and Meaning of Data for Bubble Test

3.5 Command CmdRestart

The bubble sensor jumps to address **0000** of the internal program and starts with initial test. The outlet is set to fault status.

In case of an unintended executed command, the superior control unit recognizes the fault status during the initial test and can react accordingly.

Frame	**F1H / 00H / 05H / 16H / CRC**

Table 19: Frame for command Restart

3.6 Command CmdPing

This command is available in dialog mode only (Mode 3), for test of communication.

Request:

Frame	**F1H / 00H / 05H / 29H / CRC**

Response:

ACK	**11H**

Table 20: Frame for command Ping

3.7 Command CmdGetIdent

This command is available in dialog mode only (Mode 3).

Get information about versions and internal addresses.

Request

Frame	F1H / 00H / 05H / 25H / CRC

Respond

Frame	F1H / 00H / 15H / 25H / Data / CRC	
Byte of Data	**Data**	
0	`ID_DeviceType`	=20 / means Air Bubble Detector
1	`ID_SensorType`	Code for type of sensor 05 = series ABD05 06 = series ABD06 07 = series ABD07 08 = series ABD08
2	`ID_Sensor SubType`	Code for subtype of sensor **1, e.g. e.g. ABD05: 50 = series ABD05.50 … .57
3	`ID_Hardware`	Code for type of board **1
4/5	`ID_Firmware`	L/H: Code for software version, e.g. 141 = V1.41
6/7	`ID_CPar`	L/H. Address of parameter section, e.g. 0A00H
8/9	`ID_ParSize`	L/H. Size of parameter section, e.g. 0200H
10/11	`ID_Boot`	L/H. Address of boot section, e.g. 1A00H
12	`ID_Version`	SW V1.30: version code **1
	`ID_Model`	SW V1.40 or higher: Model No. or Specification **1, if defined
13	`ID_Year`	V1.40 or higher: Year of manufacturing, e.g. 12 = 2012
14/15	`ID_SN`	V1.40 or higher: L/H. Serial Number of Sensor

**1: Code depends on type of sensors or specification. For more details please contact our service staff.

Table 21: Frame for Identification Vector

3.8 Command CmdGetvalues

This command is available in dialog mode only (Mode 3).

Get information about internal values.

Request

Frame	**F1H / 00H / 05H / 23H / CRC**

Respond

Frame	**F1H / 00H / 16H / 23H / Data / CRC**
Byte of Data	**Data**
0 … 15	Data: for meaning see table in chapter 4.4.
16	Bubble Size for meaning see table in chapter 4.2.

Table 22: Frame for Measuring Values

4 Notes to Serial Transferred Data

4.1 Start Pattern

Start Pattern	Meaning
F1H	Start pattern for serial commands sent to sensor. Mode 3: Start pattern for response frame.
FEH	Mode 1: Start pattern for frames sent from sensor
FFH	Mode 2: Start pattern for frames sent from sensor
11H	Mode 3: ACK for commands (single byte):

Table 23: Start Pattern

Using the start pattern the machine is able to synchronize the data stream sent from sensor in unique way. No other transmitted byte is set to FFH or FEH. The start patterns for Mode 1 (normal) and 2 (service) are different. This allows to distinguish between the different protocols.

4.2 Bubble Size

The measurement result (bubble size) will be given out in a cycle time of 1ms.

Bubble Size	Meaning
0 to 50	No or very small bubbles occurred.
50 to 239	Medium sized bubbles occurred. These bubbles should be acquired and added by the machine.
240	Large sized bubbles occurred, the machine must react.
241	A critical error occurred.

Table 24: Coded Signal for Bubble Size

4.3 Pointer

The pointer will be incremented after each cycle of serial output.

The 7th bit of data is moved to the 7th bit of the pointer and set to 0. This prevents mistakes in case the data is equal to the start pattern FFH or FEH. The control unit is able to decode the result in the right way.

4.4 Data

The bubble sensor transmits in Mode 2 an array of 16 bytes for data via the serial interface, one byte in each serial output cycle of 1 ms. That means, after 16 ms the array of measured values is transmitted completely.

Byte	Data
0/1	H/L byte of ADC offset (10 bit)
2/3	H/L byte of ADC value of amplitude (10 bit)
4/5	H/L byte of linear ADC value with offset correction (10 bit)
6	Calculated logarithmic value of amplitude (8 bit, resolution 0.1 dB)
7	Maximum of amplitude, for adjusting measuring range
8	Step of gain of amplifier (0 to 4), 10 dB per step
9	**Alarm Flags** Bit 0: EMI alarm Bit 1: Bubble alarm Bit 2: Adjusting, out of range Bit 3: Gain test, out of range Bit 4: Amplitude test failed Bit 5: Synchronization is off Bit 6 to 7: Not used
10	**Get State and Control Flags** Bit 0: LED green (= 1: LED is on) Bit 1: LED red (= 1: LED is on) Bit 2: LED blue (= 1: LED is on) Bit 3: = 0: LEDs are controlled by serial command from the machine = 1: LEDs are set depend on state of sensor (default) Bit 4 to 7: Do not care about
11	Sum of bubbles over the last 80 measuring cycles (16 ms), divided by 256
12	Error code
13/14	Internal values for investigations of causes for faults (depending on the self-test routine triggering the fault)
15	Code for version of hard- and firmware

Table 25: Transferred Measuring Data (long protocol only).
[Order or meaning of the data depending on the version of bubble sensor.]

4.5 Error Code

The value is transmitted as data byte (no. 12) in case of a fault.

Error Code	Value	Self-Test Routine Triggering the Fault
FC_PCI	81H	Progress check for initial test
FC_PCM	82H	Progress check for measuring mode
FC_CRC	83H	CRC test
FC_RAM	84H	RAM test
FC_Stack	85H	Stack test
FC_GainTest	86H	Amplifier and ADC test, out of range
FC_ChP	87H	Checksum of settings
FC_ChABDSwitch	88H	Check of switching output
FC_CPU_ALU	8AH	CPU ALU test
FC_CPU_JMP	8BH	CPU JMP test
FC_CPU_MOV	8CH	CPU MOV test
FC_WD_Timing	8DH	Watchdog test timing
FC_WD_Monitor	8EH	Watchdog test voltage monitor

Table 26: Error Code in Case of a Fault

4.6 CRC

The CRC is calculated with data bytes using the polynomial D4H and start value FEH/FFH, depending on serial protocol mode. After the calculation the result will be cut to 6 bits. The leading 2 bits will be set to 0 (preventing the forbidden value FEH or FFH, start pattern).

Using the CRC the machine can check the correct transmission of serial data stream.

```
//-----------------------------------------------------------
function TMainForm.GetCRC: byte;
var i, Ct: integer;
    a, b: byte;
const CRC_Serial = $D4;
begin

// Buffer: 1. byte = start value / 2. ...x-1. byte = data / x. byte = CRC

// Ct: count of bytes in buffer: standard protocol = 3, service protocol = 5

// b: start value: standard protocol = $fe, service protocol = $ff


  Ct:=3;    // ct = 3 for standard protocol

  b:=$fe;   // b = start value for standard protocol = 1. byte


  for i:=1 to Ct-2 do begin
    a:= b xor Buffer[i];
    if (a shr 7) <> 0 then b:=(a shl 1) xor CRC_Serial
                      else b:=(a shl 1);
  end;

  Result:= b and $3F;
end;
//-----------------------------------------------------------
```

Example for Code Implementation for CRC