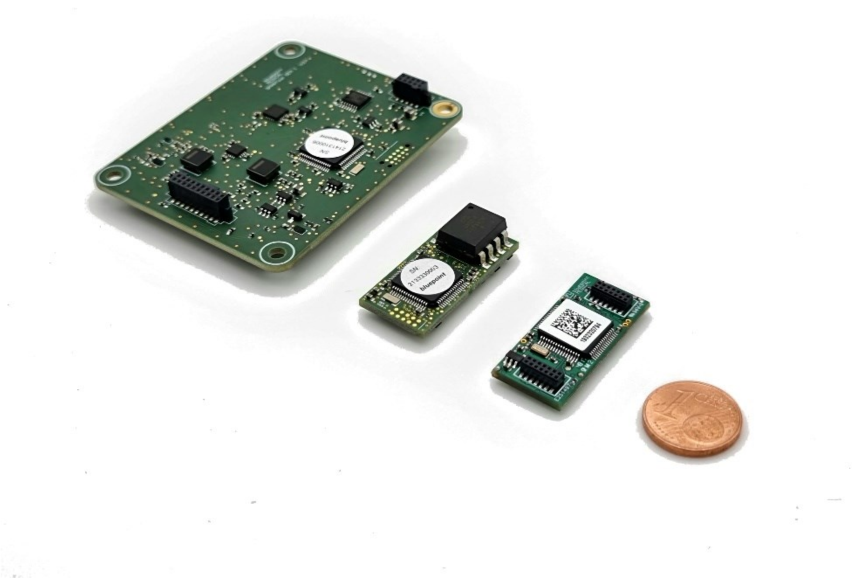
Communication Protocol

SMARTsat® OEM I/ II/ III



COMPANY CONFIDENTIAL

This document is the property of Bluepoint MEDICAL GmbH & Co. KG and is protected by German and international copyright law, and may not, without the written permission by Bluepoint MEDICAL GmbH & Co. KG, be given to any third parties.

Table of Contents

SMARTsat® Communication Protocol

Document number: O-07-00-002

Document Revision: 16

Released: 01/2023

Communication Protocol Rev.: 16

The information in this document is subject to change.

NOTE: Throughout this document, a point is used as the decimal separator.

Copyright © 2016 bluepoint MEDICAL GmbH & Co. KG. All Rights Reserved.
This document contains proprietary information that is protected by copyright. All rights are reserved. No part of this document may be photocopied, reproduced or translated to another language without prior written consent of bluepoint MEDICAL GmbH & Co. KG.

Contact information

bluepoint MEDICAL GmbH & Co. KG
An der Trave 15
23923 Selmsdorf
Germany

Phone:	+49-(0)-38823-5488-0
Fax:	+49-(0)-38823-5488-29
E-mail:	info@bluepoint-medical.com
Web:	https://www.bluepoint-medical.com/

1 Transmission characteristics

1.1 Physical layer

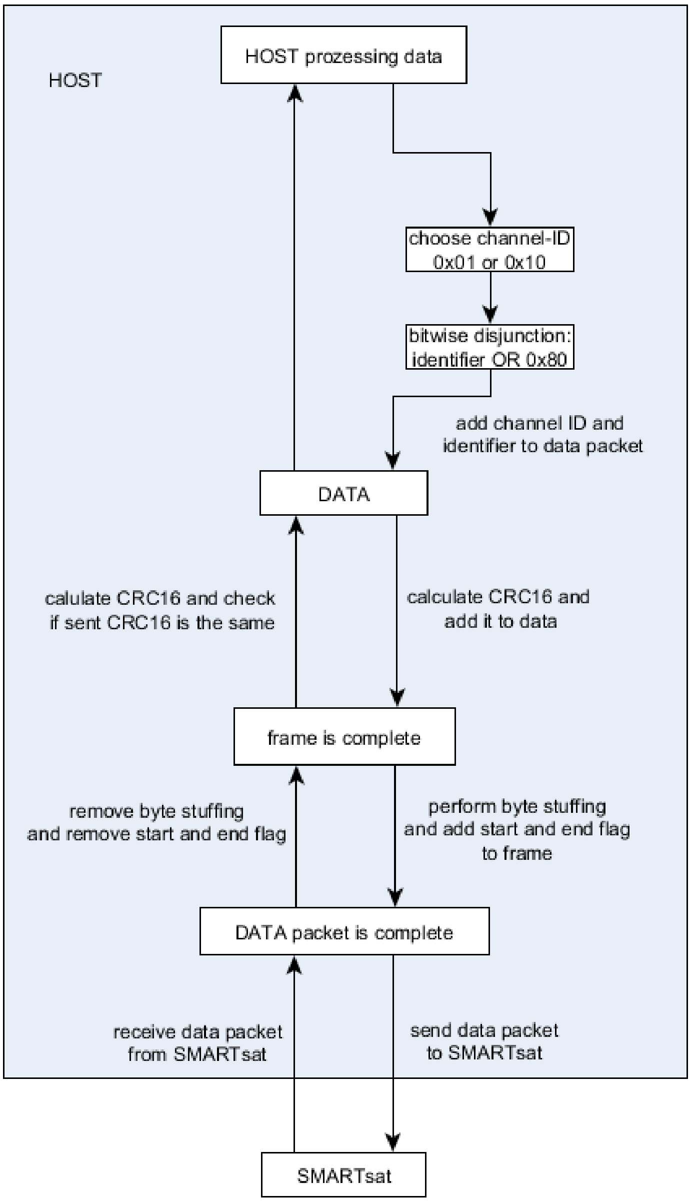
Serial UART interface:

- Baud rate is variable, default: 115200 Bd
- 1 start bit, 8 data bits, 1 stop bit, no parity bits (8-N-1)
- No hard or software handshake is used

1.2 Data-link layer

The data sent to the SMARTsat® module and received from it, is transmitted as packet. Each packet consists of a number of bytes. In general the SMARTsat® protocol is based on the „Serial Line Internet Protocol“.

The SMARTsat® module data packets are sent continuously. The package structure is described in section 2.2. The host command packets are sent occasionally as needed. The package structure is similar to the SMARTsat® module data packets, however no frame counter is sent and the identifier (ID) is linked with the attribute 0x80 OR (refer to 2.3). The figure below presents the data flow.


HOST
HOST prozessing data
choose channel-ID 0x01 or 0x10
bitwise disjunction: identifier OR 0x80
add channel ID and identifier to data packet
DATA
calulate CRC16 and check if sent CRC16 is the same
calculate CRC16 and add it to data
frame is complete
remove byte stuffing and remove start and end flag
perform byte stuffing and add start and end flag to frame
DATA packet is complete
receive data packet from SMARTsat
send data packet to SMARTsat
SMARTsat

1.3 Host transmission wake-up sequence

Each command send from host to SMARTsat® OEM must be initiated by a **Wake-Up byte**.

This Wake-Up byte is necessary to ensure that no data is lost while the module is in a power save mode. The impressive low power consumption of the SMARTsat® OEM III is achieved due to this feature.

At the beginning of each command the host therefore needs to send one byte of data as Wake-Up byte to SMARTsat® (for example 0x77).

To start communication, send a wake-up byte (e.g. 0x77). Then send the data frame within 1 to 10ms after sending the wake-up byte.

For PC-applications e.g. written in C# a stopwatch timer is required to ensure the delay time stays within specifications (thread sleep methods are inaccurate).

After the delay time the transmission is completed by sending the data frame.

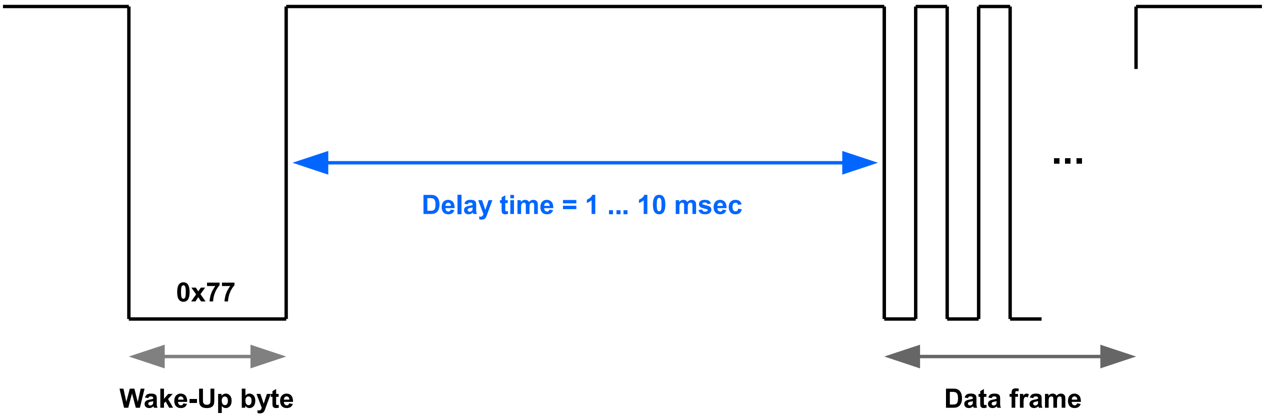


Figure 1-1: Timing of wake-up sequence

Example on how to request the device ID:

```
UART_Send(0x77);        // Send Wake-up byte
WaitMs(1);              // Wait 1-10 ms
UART_Send(0xA8);        // Send command
UART_Send(0x01);        //
UART_Send(0x02|0x80);   //
UART_Send(0x41);        //
UART_Send(0x80);        //
UART_Send(0xA8);        //
```

NOTE: Depending on baud rate a limited number of commands send by the host can be evaluated each second (at 9600 Bd smallest number). The *receive buffer overflow flag* is send, if this limit is reached.

2 Data packet structure

Each data packet received from SMARTsat® or command sent to the SMARTsat® has the following structure:

Packet			
Start Flag	Frame		End Flag
Start Flag	Data	CRC16	End Flag

2.1 Data packet description

Start Flag	Data	CRC16	End Flag

Name	**Description**	**Size**
Start flag	Indicates the beginning of a frame: 0xA8	1 byte
Data	Data field	variable
CRC16	CRC16 data verification as indicated below from all characters in the field 'Data'. Send: High byte first	2 bytes
End flag	Indicates the end of a packet: 0xA8	1 byte

2.2 Read sent SMARTsat® frames

2.2.1 Start and end flags

Start and end flags are used to find single frames in the data stream.

Start flag: **0xA8**	Frame		End flag: **0xA8**
Start flag: **0xA8**	Data	CRC16	End flag: **0xA8**

Both flags have the value **0xA8.** Find the bytes between the **0xA8** in the data stream to identify a frame. If there is no data between the **0xA8,** it is the start of a frame. In the next step the frame requires de-stuffing (refer to section 2.2.2)

2.2.2 Byte stuffing

Flag	Frame	Flag

SMARTsat® uses a byte-stuffing algorithm on each frame to ensure that no 0xA8 is transmitted within the frame.

The reserved value 0xA8 is used for the start and end flags. The second reserved character is the control byte with value 0xA9. If in the block “data” or “CRC16” a byte is equal to 0xA8 or 0xA9, the byte is coded and replaced as follows:

- 0xA8 ≙ 0xA9 0x88
- 0xA9 ≙ 0xA9 0x89

The host can then clearly detect where one packet ends and the next one begins because **0xA8** is reserved to the start and end flags and will never show up within the frame.

If in the received data stream a control byte is detected, it is to be ignored and on the following byte the bitwise disjunction “byte OR 0x20” is execute (de-stuffing).

E.g.:

Packet sent by SMARTsat®	A8 FE 10 02 2A 32 3D 4B 5C 6C 7E 8F 9E A9 89 AF B0 AE A9 88 A1 00 80 A4 7E A8
Frame which must be de-stuffed	FE 10 02 2A 32 3D 4B 5C 6C 7E 8F 9E A9 89 AF B0 AE A9 88 A1 00 80 A4 7E
Frame after de-stuffing	FE 10 02 2A 32 3D 4B 5C 6C 7E 8F 9E A9 AF B0 AE A8 A1 00 80 A4 7E

After de-stuffing calculate the CRC according to section 2.2.3 to ensure data validity.

2.2.3 CRC16 data verification

The integrity of the data received is verified by calculating the CRC16 check value of the “DATA” field and comparing it with the CRC16 check value sent in the frame. 0xFFFF is the starting value.

Start flag	Data	CRC16	End flag

Example for CRC16 (cyclic redundancy check) in C:

```
const unsigned short wCRCTableAbs[] =
{
 0x0000, 0xCC01, 0xD801, 0x1400, 0xF001, 0x3C00, 0x2800, 0xE401,
 0xA001, 0x6C00, 0x7800, 0xB401, 0x5000, 0x9C01, 0x8801, 0x4400,
};

unsigned short _Data2CRC16(char *pchMsg, unsigned short wDataLen )
{
    unsigned short i,  wCRC = 0xFFFF;
    char chChar;

    for (i = 0; i < wDataLen; i++)
    {
         chChar = *pchMsg++;
         wCRC = wCRCTableAbs[(chChar ^ wCRC) & 15] ^ (wCRC >> 4);
         wCRC = wCRCTableAbs[((chChar >> 4) ^ wCRC) & 15] ^ (wCRC >> 4);
    }

    return wCRC;
}
```

2.2.4 SMARTsat® data structure

The Data sent by the SMARTsat® has the following structure:

Flag	Data				CRC16	Flag
Flag	Frame counter	Channel (Ch)	Identifier (ID)	Value	CRC16	Flag
1 byte	1 byte	1 byte	1 byte	various bytes	2 bytes	1 byte

2.2.4.1 Frame counter

Each data packet sent from the SMARTsat® module is consecutively numbered (frame counter).

Flag	Frame counter	Channel (Ch)	Identifier (ID)	Value	CRC16	Flag

The frame counter is used to detect data packets lost during data transmission. The frame counter is an unsigned 8 bit value ranging from 0 to 255. It begins with 0 and is incremented with each data block. After reaching the frame counter 255, the next number will be set to 0, and so on.

2.2.4.2 Channel

The protocol differentiates the data by using a channel.

Flag	Frame counter	Channel (Ch)	Identifier (ID)	Value	CRC16	Flag

The following channels are available:

Channel (Ch)	**Name**	**Description**
0x01	Common device channel	Identifies the module hardware and firmware
0x02	Error channel	List of errors detected by SMARTsat®
0x10	SMARTsat® channel	Channel for configuration of SMARTsat® and receiving the measurement results and parameters.

2.2.4.3 Identifier

The data identifier is used to differentiate the different module parameters and values sent within each channel. Possible identifiers for each channel are listed in the section 3.3.

Flag	Frame counter	Channel (Ch)	Identifier (ID)	Value	CRC16	Flag

2.2.4.4 Data values

The relevant information transported by the data package is coded in the VALUE of the Common device information channel (refer to section 3.1) and the SMARTsat® channel (refer to section 3.3).

Flag	Frame counter	Channel (Ch)	Identifier (ID)	Value	CRC16	Flag

In case of the Error channel, the relevant information is coded in the Identifier (ID), refer to section 3.2.

2.2.5 SMARTsat® data - Summary

The table below lists the data options transmitted by SMARTsat® including information on options to change the data format.

Note that all available host commands are also listed in section 2.3.3. For the specification of the communication protocol itself, refer to section 3 of this document.

Name	Ch	ID	Description
Identification	0x01	Refer to 3.1	Common device channel used to transmit the device identification data (e.g. SN, type and FW version) at start up and upon request.
	0x10	0x06	Upon request the connected sensor type is transmitted.
Error	0x02	Refer to 3.2	Error information transmitted in the error channel at 1 Hz for the duration of error occurrence.
Status information	0x10	0x01	Technical and physiological pulse oximetry status information is transmitted at selected sending frequency. → select send frequency with *ID 0x17*
Waveform data ***NOTE:*** only one waveform type can be selected at a time	0x10	0x02	Normalized Auto Scaled Plethysmogram (ASP) with pulse beep indicator acquired at 75Hz sampling rate transmitted as: - 15 data point block at 5 Hz **or** - 1 data point block at 75 Hz → set data format with *ID 0x18* *Note:* before activating ASP, first deactivate RP/ RP2.
		0x03	Raw Plethysmogram of infrared signal (RP) transmitted as single data point at selected sample rate (SR). → activate RP with *ID 0x19* → select sample rate with *ID 0x1A* *Note:* The current activated plethysmogram type (ASP/ RP2) is automatically deactivated in case RP is activated.
		0x07	Raw Plethysmogram of red and infrared signals (RP2) sent as data block including the data point of both wavelength at selected sample rate (SR). → activate RP2 with *ID 0x1B* → select sample rate with *ID 0x1A* *Note:* The current activated plethysmogram type (ASP/ RP) is automatically deactivated in case RP2 is activated.
Results and indicators ***NOTE:*** only one Results and Indicators format can be selected at a time	0x10	0x04	Measurement Results and Indicators with SpO_2 integer representation (e.g. 94%) transmitted at 1Hz. → activate integer representation of SpO_2 results with *ID 0x1C* In this format the following perfusion index (PI) resolution options are available: - PI with 1 decimal digit resolution (0.1%) **or** - PI with 2 decimal digit resolution (0.01%) → select PI resolution with *ID 0x1D*
		0x05	Measurement Results and Indicators with SpO_2 float representation with two decimal digits (e.g. 94.18%) transmitted at 1Hz → activate float representation of SpO_2 results with *ID 0x1C* In this option the perfusion index resolution is not selectable and set to 2 decimal digit resolution (0.01%)

2.3 Commands sent by host

2.3.1 Build frame

Building frames is done in reverse order to reading the frames. First identify data to be sent (refer to section 3.3). Execute a bitwise disjunction with the identifier (ID) and 0x80.

Now calculate the CRC16 (section 2.2.3) to complete the frame.

Perform byte stuffing on the complete frame (section 2.2.2), thereafter add the start and end flag.

The command package is ready to be sent to the SMARTsat®.

2.3.2 Command frame structure

Commands sent by the host to SMARTsat® must be sent in the following data packet structure:

Flag	Data			CRC16	Flag
Flag	Channel (Ch)	Identifier (ID) ***OR*** 0x80	Value	CRC16	Flag

The time between two consecutive commands sent to SMARTsat® has to be larger than 100ms. The SMARTsat® confirms the command. Send the command again, if the command is not confirmed within 100ms.

The data included in a command package is described in the table below.

Item	**Description for commands sent by host** (refer to section 2.2.4 for description of the SMARTsat® data structure)
Frame counter	**NOTE:** No frame counter is included in the command packages sent by the host to SMARTsat®
Channel (Ch)	Commands sent by the host and data sent by SMARTsat® use the same channel. Refer to section 2.2.4.2.
Identifier (ID)	For commands sent by the host a bitwise disjunction of the data identifier and the ***attribute 0x80*** shall be performed***.*** Possible identifiers for each channel are listed in the section 3.3. e.g. host identifier = 0x31|0x80 = 0xB1 **NOTE:** For messages from SMARTsat® to the host (Answer), the Identifier has no attribute and the relevant information follows in further bytes.
Command value	A command is sent by the host to SMARTsat® to change a mode or to ask for the current setting. A VALUE is included in the data package, depending on the type of request.

At any time the host can ask for the current setting within the SMARTsat® channel or request common device information.

In this case no VALUE is included in the package if the command value size is defined as 0 Byte:

Flag	Channel (Ch)	Identifier (ID) ***OR*** 0x80	CRC16	Flag

Example in HEX - Request which sensor type is connected:

```
A8 10 86 D2 8D A8
```

Also refer to section 3.3, column: “Host command value size” is set to 0 Byte in case an identifier can be requested.

If set to n/a, it is not possible to request the identifier.

If the “command value size” is > 0 Byte, refer to section 2.3.3 for more detail.

2.3.3 Commands

Available host commands are transmitted in the SMARTsat® channel 0x10.

A command frame always carries at least one byte-sized value (refer to section 3.3, column "Host command value size"). Current commands are listed in the table below. Customized commands are listed in customer specific attachments.

ID [1] (Ch 0x10)	Description	Range	Default [2]
0x10	Response time setting (SpO_2 and Pulse Rate)	stable / standard / sensitive / 8-Beat / 4-Beat	standard
0x12	Pulse rate mode	30 to 240 bpm / 20 to 300 bpm	30 to 240 bpm
0x17	Status information send frequency	5 Hz / 1 Hz	5 Hz
0x18	Auto Scaled Plethysmogram (ASP)	off / 15 points@5Hz / 1 point@75Hz	15 points@5Hz
0x19	Raw Plethysmogram of infrared signal (RP) at selected sample rate	On / Off	Off
0x1A	Sample Rate (SR)	75 Hz / 300 Hz	75 Hz
0x1B	Raw Plethysmogram of red and infrared signal (RP2) at selected sample rate	On / Off	Off
0x1C	Resolution of SpO_2 results	integer / two dec. digits	integer
0x1D	Resolution of perfusion index (PI)	one dec. digit / two dec. digits	two dec. digits
0x30	Perform SMARTsat® Module Software Reset	n/a	n/a
0x31	Baud rate setting	9600 Bd to 230400 Bd	115200 Bd

[1] Refer to section 3.3 for more detail

[2] Customized default start up setting configurations possible, depending on order quantity

3 Communication protocol

3.1 Common device channel 0x01

ID	Value	SMARTsat® data value size	Host command value size
0x01	Protocol version as string E.g. “Rev.16”	variable (max. 16 Bytes)	0 Bytes
0x02	Device identification (module ID) as string E.g. “01” = SMARTsat® OEM I “03” = SMARTsat® OEM III “07” = SMARTsat® OEM II	Variable (max. 4 Bytes)	0 Bytes
0x03	Firmware version as string E.g. “BM.03.B36.A24.1B”	Variable (max. 64 Bytes)	0 Bytes
0x04	Hardware version as string E.g. “V3.3.1 Rev.B”	Variable (max. 24 Bytes)	0 Bytes
0x05	Serial number as string E.g. “1828320001”	10 Bytes	0 Bytes
0x06	Sent once at device start-up and reset. SMARTsat® always starts with default settings[1] except for Baud rate which starts at last selected setting. **NOTE:** At repeated reset of the module, the host is recommended to display message “Device Defective”. A typical reason for a reset of the module is an unstable or fluctuating supply voltage. **WARNING:** Check the user-settable parameter listed in section 2.3.3 each time SMARTsat® sends the start-up frame during operation to ensure the settings are still selected as intended.	0 Bytes	n/a

[1] Customized default start up setting configurations possible, depending on order quantity

NOTE: Each time the module is switched on (also after reset) it will send the start-up frame, firmware version and serial number.

Example in HEX at start-up for FW “BM.03.B36.A24.1B” and SN “1828320001”:

```
Start-up frame: A8 00 01 06 52 F0 A8
FW: A8 01 01 03 42 4D 2E 30 33 2E 42 33 36 2E 41 32 34 2E 31 42 5C 52 A8
SN: A8 02 01 05 31 38 32 38 33 32 30 30 30 31 8F 57 A8
```

3.2 Error channel 0x02

If the SMARTsat® module receives faulty data packets or detects an internal module error, the corresponding error message will be sent to the host. The SMARTsat® module does not accept any messages on this channel.

Error messages are transmitted for the duration of error occurrence at 1 Hz on the channel 0x02 according to the structure below.

Flag	Frame counter	0x02	Identifier (ID)	CRC16	Flag

The errors are listed in the table below.

Error channel 0x02:

ID	Error	Description
0x01	Unknown channel	SMARTsat received a command with unknown channel.
0x02	Unknown identifier	SMARTsat received a command with unknown identifier.
0x03	Invalid value	SMARTsat received a command with invalid value (e.g. a not defined baud rate).
0x04	Selected baud rate is to slow	For activation of the Raw Plethysmogram (RP) set at minimum baud rate of 115200 Bd.
0x05	Receive buffer overflow	SMARTsat is receiving too much data
0x06	Frame corrupt, CRC error	SMARTsat is receiving data packets with Frame corrupt or CRC error
0x07	Sensor Error: Red LED defective	The red LED at the sensor is defective. **NOTE**: status information 'Sensor defective' (Byte[0] Bit: 1 in channel 0x10, identifier 0x01) is sent at the same time .
0x08	Sensor Error: Infrared LED defective	The infrared LED at the sensor is defective. **NOTE**: status information 'Sensor defective' (Byte[0] Bit: 1 in channel 0x10, identifier 0x01) is sent at the same time .
0x09	Sensor Error: Photodiode defective	The detector at the sensor is defective. **NOTE**: status information 'Sensor defective' (Byte[0] Bit: 1 in channel 0x10, identifier 0x01) is sent at the same time .
0x0A	Sensor Error: Short circuit	Short circuit occurred in the sensor cable or connector. Measurement is interrupted. Disconnect sensor to reset the error.
0x10	Boot error	The boot-test during module switch-on failed.
0x11	Self-test error	During module switch-on a self-test is performed. This error is sent if the self-test failed
0x12	Buffer overflow	An internal buffer overflow error occurred and module restarts after sending the error message. **NOTE:** if the error message repeats, display a technical error message for at least 1 second upon occurrence of the error
0x13	Command to switch on Auto Scaled Plethysmogram (ASP) is not accepted	Auto Scaled Plethysmogram (ASP) cannot be switched on while Raw Plethysmogram (RP) or two wavelength Raw Plethysmogram (RP2) is activated. First switch off the RP or RP2 before switching on the ASP.

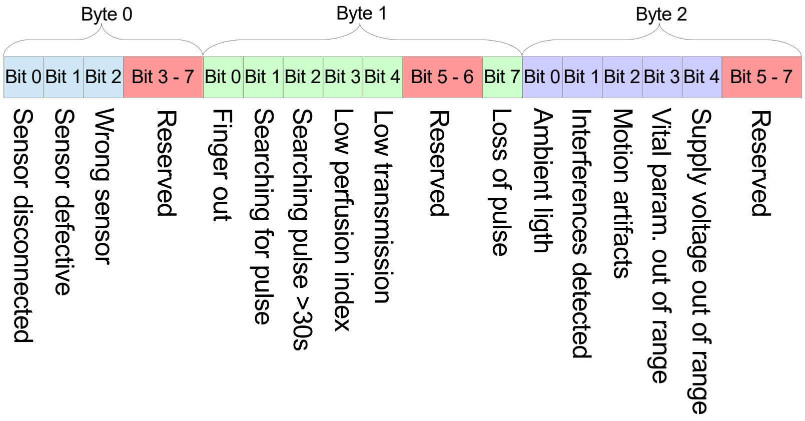
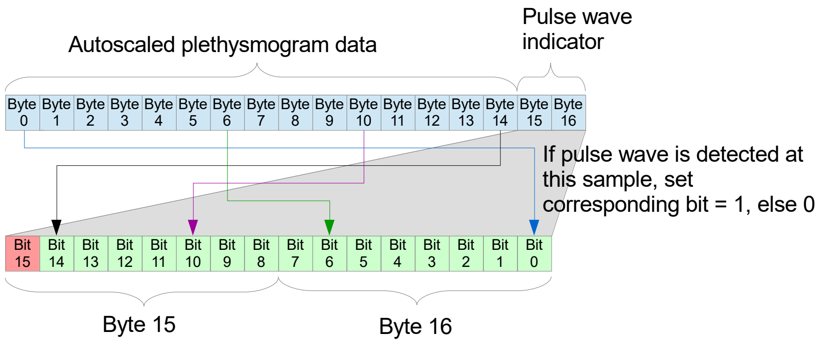
Example in HEX:

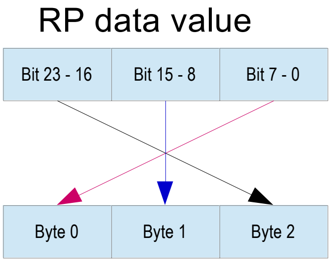
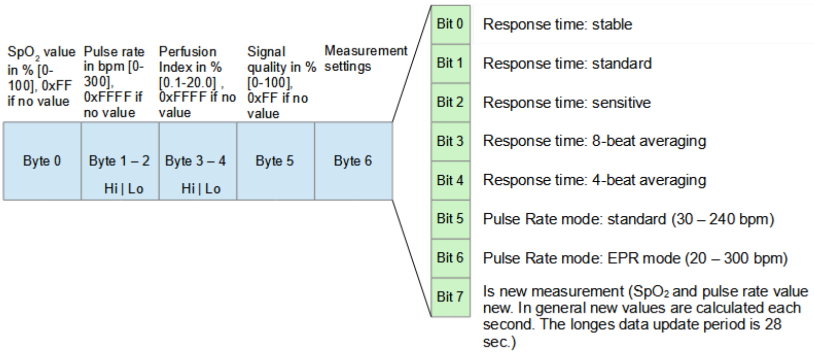
The following package is sent by SMARTsat® if the host sends a command with unknown identifier:

```
A8 53 02 02 70 01 A8
```

3.3 SMARTsat® channel 0x10

ID	Value *(*for description to build the Host Command refer to section 2.3)*	SMARTsat®		* Host Com. Value size
		Send freq.	**Size**	
0x01	**Status information (if Bit is set to 1)** *Byte*[0]: Bit 0: Sensor disconnected Bit 1: Sensor defective Bit 2: Wrong sensor Bit 3-7: Reserved *Byte*[1]: Bit 0: Probe off Bit 1: Searching for pulse Bit 2: Pulse searching longer than 30 sec Bit 3: Low perfusion index (IR AC/DC ratio <1%) Bit 4: Low transmission Bit 5-6: Reserved Bit 7: Loss of pulse (no value is displayed; typically due to prolonged bad signal quality) Alarm monitors should give at least medium priority alarm if this bit is set *Byte*[2]: Bit 0: Ambient light Bit 1: Interferences detected Bit 2: Motion artifacts Bit 3: Vital parameter out of range Bit 4: Supply voltage out of range Bit 5 - 7: Reserved	5 Hz (default) / 1 Hz	3 Bytes	0 Bytes

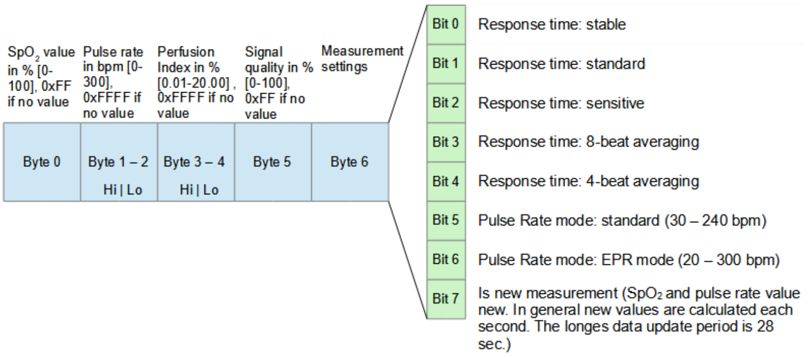
ID	**Value** *(*for description to build the Host Command refer to section 2.3)*	SMARTsat®		* Host Com. Value size
		Send freq.	**Size**	
	 Byte 0 Byte 1 Byte 2 Bit 0 Bit 1 Bit 2 Bit 3 - 7 Bit 0 Bit 1 Bit 2 Bit 3 Bit 4 Bit 5 - 6 Bit 7 Bit 0 Bit 1 Bit 2 Bit 3 Bit 4 Bit 5 - 7 Sensor disconnected Sensor defective Wrong sensor Reserved Finger out Searching for pulse Searching pulse >30s Low perfusion index Low transmission Reserved Loss of pulse Ambient ligth Interferences detected Motion artifacts Vital param. out of range Supply voltage out of range Reserved The SMARTsat® module sends the status information setting continuously five times each second (5 Hz). Sending frequency can be changed to 1 Hz (see identifier ID: 0x17). Byte[0] is sent first.			
0x02	**Auto Scaled Plethysmogram (ASP) with pulse beep indicator** The ASP is a normalized waveform with constant amplitude independent of the actual magnitude of the signal. The format of this data depends on the selected Auto Scaled Plethysmogram setting (identifier 0x18).			
	1) Identifier 0x18 → 0x01; ASP with 15 points @ 5 Hz			
	Byte [0-14]: The Auto Scaled Plethysmogram (ASP) data block with 15 samples. Resolution: 8-bit at 75Hz. *Byte* [15-16]: The pulse beep indicator is represented by an array of 15 bits (Byte 15 and 16) corresponding to the 15 plethysmogram data points in Byte 0 to 14. If a heartbeat is detected in sample 0 … 14, the corresponding bit is set to 1, otherwise the bit is 0. The high byte is sent first as indicated below. The pulse beep indicator with reference to the plethysmogram samples is graphically described below:  Autoscaled plethysmogram data Pulse wave indicator Byte 0 Byte 1 Byte 2 Byte 3 Byte 4 Byte 5 Byte 6 Byte 7 Byte 8 Byte 9 Byte 10 Byte 11 Byte 12 Byte 13 Byte 14 Byte 15 Byte 16 If pulse wave is detected at this sample, set corresponding bit = 1, else 0 Bit 15 Bit 14 Bit 13 Bit 12 Bit 11 Bit 10 Bit 9 Bit 8 Bit 7 Bit 6 Bit 5 Bit 4 Bit 3 Bit 2 Bit 1 Bit 0 Byte 15 Byte 16 The SMARTsat® module sends the plethysmogram continuously 5 times each second (5 Hz). Sending can be switched off (see identifier: 0x18)	5 Hz (default) / 0 Hz	17 Bytes	n. a.

ID	**Value** *(*for description to build the Host Command refer to section 2.3)*	SMARTsat®		* Host Com. Value size
		Send freq.	**Size**	
	2) Identifier 0x18 → 0x03; ASP with 1 point @ 75 Hz			
	Byte [0]: one byte of Auto Scaled Plethysmogram (ASP) (8-bit resolution) *Byte* [1]: pulse beep indicator. If byte[1] = 0, no pulse was detected at that time. If byte[1] = 1, a pulse was detected and the pulse beep may sound. The SMARTsat® module sends the plethysmogram continuously 75 times each second (75 Hz). Sending can be switched off (see identifier 0x18)	75 Hz / 0 Hz	2 Bytes	n. a.
0x03	**Raw Plethysmogram of the infrared signal (RP)** This data is activated by using identifier 0x19. *Byte*[0-2]: Raw Plethysmogram (RP) data block with one sample (data point). Each plethysmogram data sample is an unsigned 24 bit value represented by three bytes. The lowest byte (Byte 0) is sent first. The RP data send order is described below:  RP data value Bit 23 - 16 Bit 15 - 8 Bit 7 - 0 Byte 0 Byte 1 Byte 2 The time resolution of the plethysmogram is defined by the selected sample rate setting (0x1A). It can be set to 75Hz or 300 Hz sample rate The default setting is 0 Hz (off) The data samples are sent at a constant delay of: - 13.3 ms in 75Hz sample rate - 3.3 ms in the 300Hz sample rate No data is sent if the “Probe off” status is active.	0 Hz (default) / 75 Hz / 300 Hz	3 Bytes	n. a.
0x04	**Results and Indicators with SpO_2 integer representation** This data is activated by using identifier 0x1C. The format of this data depends on the selected setting for the resolution of the perfusion index (PI) (identifier 0x1D).			
	a) Format with identifier 0x1D → 0x01 = resolution of PI is 0.1%			
	 SpO2 value in % [0-100], 0xFF if no value Pulse rate in bpm [0-300], 0xFFFF if no value Perfusion Index in % [0.1-20.0] , 0xFFFF if no value Signal quality in % [0-100], 0xFF if no value Measurement settings Byte 0 Byte 1 – 2 Hi | Lo Byte 3 – 4 Hi | Lo Byte 5 Byte 6 Bit 0 Response time: stable Bit 1 Response time: standard Bit 2 Response time: sensitive Bit 3 Response time: 8-beat averaging Bit 4 Response time: 4-beat averaging Bit 5 Pulse Rate mode: standard (30 – 240 bpm) Bit 6 Pulse Rate mode: EPR mode (20 – 300 bpm) Bit 7 Is new measurement (SpO2 and pulse rate value new. In general new values are calculated each second. The longes data update period is 28 sec.)	1 Hz / 0 Hz	7 Bytes	0 Bytes

<table>
<tr><th rowspan="2">ID</th><th rowspan="2">Value <em>(*for description to build the Host Command refer to section 2.3)</em></th><th colspan="2">SMARTsat®</th><th rowspan="2">* Host Com. Value size</th></tr>
<tr><th>Send freq.</th><th>Size</th></tr>
<tr><td></td><td>
<em>Byte</em>[0]: SpO2 Value
[1…100 %], 0xFF = no value

<em>Byte</em>[1-2]: Pulse rate
[x…300 bpm], 0xFFFF = no value, (Hi+Lo)
x = 20 bpm, EPR on
x = 30 bpm, EPR off
<em>Byte</em>[3-4]: Perfusion Index PI= I_{AC}/I_{DC}
[0.1...20 %], 0xFFFF = no value,
1 digit ≙ 0.1 %
e.g.:
0x0005 =   5 dec. ≙ 0.5 %
0x0064 = 100 dec. ≙ 10 %

<em>Byte</em>[5]: Signal quality (indicator to show signal inadequacy)
[1, 30, 60,100 %],
<table>
<tr><td>100%:</td><td>Good signal quality resulting in accurate measurement values.</td></tr>
<tr><td>60%:</td><td>Reduced signal quality, which may reduce measurement accuracy. Also applies if following flags are set:
- “Supply voltage out of range”
- “Vital parameter out of range“</td></tr>
<tr><td>30%</td><td>Poor signal quality, measurement values may be inaccurate.</td></tr>
<tr><td>1%</td><td>No SpO_2 and PR measurement values available.</td></tr>
<tr><td>0xFF</td><td>No value</td></tr>
</table>
<em>Byte</em>[6]: Measurement settings (active if respective bit is set to 1)
Bit 0: Response time: stable
Bit 1: Response time: standard
Bit 2: Response time: sensitive
Bit 3: Response time: 8-Beat averaging
Bit 4: Response time: 4-Beat averaging
Bit 5: Pulse Rate mode: Standard mode (30 – 240 bpm)
Bit 6: Pulse Rate mode: EPR Mode (20 – 300 bpm)
Bit 7: New measurement (SpO_2 or pulse rate value new. In general new values are calculated each second. The longest Data Update Period is 28sec)
The high bytes are sent first.
</td><td></td><td></td><td></td></tr>
<tr><td></td><td><strong>b)</strong> Format with identifier 0x1D → 0x02 = resolution of PI is 0.01%</td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><th rowspan="2">ID</th><th rowspan="2">Value <i>(*for description to build the Host Command refer to section 2.3)</i></th><th colspan="2">SMARTsat®</th><th rowspan="2">* Host Com. Value size</th></tr>
<tr><th>Send freq.</th><th>Size</th></tr>
<tr><td></td><td>

SpO2 value in % [0-100], 0xFF if no value
Pulse rate in bpm [0-300], 0xFFFF if no value
Perfusion Index in % [0.01-20.00] , 0xFFFF if no value
Signal quality in % [0-100], 0xFF if no value
Measurement settings
Byte 0
Byte 1 – 2 Hi | Lo
Byte 3 – 4 Hi | Lo
Byte 5
Byte 6
Bit 0
Response time: stable
Bit 1
Response time: standard
Bit 2
Response time: sensitive
Bit 3
Response time: 8-beat averaging
Bit 4
Response time: 4-beat averaging
Bit 5
Pulse Rate mode: standard (30 – 240 bpm)
Bit 6
Pulse Rate mode: EPR mode (20 – 300 bpm)
Bit 7
Is new measurement (SpO2 and pulse rate value new. In general new values are calculated each second. The longes data update period is 28 sec.)

<i>Byte</i>[0]: SpO2 Value
[1…100 %], 0xFF = no value

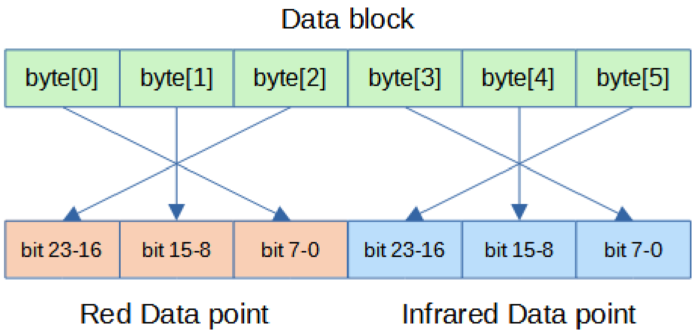
<i>Byte</i>[1-2]: Pulse rate
[x…300 bpm], 0xFFFF = no value, (Hi+Lo)
x = 20 bpm, EPR on
x= 30 bpm, EPR off

<i>Byte</i>[3-4]: Perfusion Index PI= I_{AC}/I_{DC}
[0.01...20 %], 0xFFFF = no value, (Hi+Lo),
1 digit ≙ 0.01 %
e.g.:
0x0005 = 5 dec. ≙ 0.05 %
0x0064 = 100 dec. ≙ 1 %

<i>Byte</i>[5]: Signal quality (indicator to show signal inadequacy)
[1, 30, 60, 100 %]
<table>
<tr><td>100%:</td><td>Good signal quality resulting in accurate measurement values.</td></tr>
<tr><td>60%:</td><td>Reduced signal quality, which may reduce measurement accuracy. Also applies if following flags are set:
- “Supply voltage out of range”
- “Vital parameter out of range“</td></tr>
<tr><td>30%</td><td>Poor signal quality, measurement values may be inaccurate.</td></tr>
<tr><td>1%</td><td>No SpO_2 and PR measurement values available.</td></tr>
<tr><td>0xFF</td><td>No value</td></tr>
</table>
<i>Byte</i>[6]: Measurement settings (active if respective bit is set to 1)
Bit 0: Response time: stable
Bit 1: Response time: standard
Bit 2: Response time: sensitive
Bit 3: Response time: 8-Beat averaging
Bit 4: Response time: 4-Beat averaging
</td><td>1 Hz
/
0 Hz</td><td>7 Bytes</td><td>0 Bytes</td></tr>
</table>

ID	**Value** *(*for description to build the Host Command refer to section 2.3)*	SMARTsat®		* Host Com. Value size
		Send freq.	**Size**	
	Bit 5: Pulse Rate mode: Standard mode (30 – 240 bpm) Bit 6: Pulse Rate mode: EPR Mode (20 – 300 bpm) Bit 7: New measurement (SpO_2 or pulse rate value new. In general new values are calculated each second. The longest Data Update Period is 28sec) The high bytes are sent first.			
0x05	**Results and Indicators with SpO_2 float representation (2 decimal digits)** This data is activated by using identifier 0x1C *Byte*[0-1]: SpO_2 Value [0.01…100 %], 0xFFFF = no value (Hi+Lo) 1 digit ≙ 0.01 % e.g.: 0x267C = 9852 dec ≙ 98,52 % SpO2 *Byte*[2-3]: Pulse rate [x…300 bpm], 0xFFFF = no value, (Hi+Lo) x = 20 bpm, EPR on x= 30 bpm, EPR off *Byte*[4-5]: Perfusion Index PI= I_{AC}/I_{DC} [0.01...20 %], 0xFFFF = no value, (Hi+Lo), 1 digit ≙ 0.01 % e.g.: 0x0064 = 100 dec. ≙ 1 % 0x07D0 = 2000 dec. ≙ 20 % *Byte*[6]: Signal quality (indicator to show signal inadequacy) [1, 30, 60, 100 %] 100%: Good signal quality resulting in accurate measurement values. 60%: Reduced signal quality, which may reduce measurement accuracy. Also applies if following flags are set: - “Supply voltage out of range” - “Vital parameter out of range“ 30% Poor signal quality, measurement values may be inaccurate. 1% No SpO_2 and PR measurement values available. 0xFF No value *Byte*[7]: Measurement settings (active if respective bit is set to 1) Bit 0: Response time: stable Bit 1: Response time: standard Bit 2: Response time: sensitive	1 Hz / 0 Hz	8 Bytes	0 Bytes

ID	**Value** *(*for description to build the Host Command refer to section 2.3)*	SMARTsat®		* Host Com. Value size
		Send freq.	**Size**	
	Bit 3: Response time: 8-Beat averaging Bit 4: Response time: 4-Beat averaging Bit 5: Pulse Rate mode: Standard mode (30 – 240 bpm) Bit 6: Pulse Rate mode: EPR Mode (20 – 300 bpm) Bit 7: New measurement (SpO_2 or pulse rate value new. In general new values are calculated each second. The longest Data Update Period is 28sec) The high bytes are sent first.			
0x06	**Sensor type** ***Byte*[0-1]:** sensor type value = Byte[0]*0x100 + Byte[1] **0xFFFF /65535** = undefined sensor type (see status information in identifier 0x01 for detailed reason e.g. sensor disconnected or wrong) **0x000A** /10 = Type C Sensors (closed sensors): SC7500 SoftCap; SCM7500 SoftCap medium; SCP7500 SoftCap pediatric; SF7500 SoftFlap, BF7500 Baby Foot Spotcheck Sensor **0x0028** /40 = Type O Sensors (open sensors): W7500 SoftWrap; 10-AP Disposable adult; 10-PP Disposable pediatric; 10-IP Disposable infant, Y7500 Disposable Multisite Y Sensor **0x0033** /51 = Type E Sensors (ear sensors): EP7500 Ear Probe **0x005B** /91 = Type N Sensors (neonatal sensors): 10-NP Disposable neonatal The high byte is sent first. **NOTE: Customer specific firmware with customized Sensor Type Codes are listed in a separate attachment documents**	on request	2 Bytes	0 Bytes

ID	**Value** *(*for description to build the Host Command refer to section 2.3)*	SMARTsat®		* Host Com. Value size
		Send freq.	**Size**	
0x07	**Raw Plethysmogram of the red and the infrared signal (RP2)** This data is activated by using identifier 0x1B. *Byte*[0-2]: Raw Plethysmogram data of red LED *Byte*[3-5]: Raw Plethysmogram data of infrared LED Raw Plethysmogram 2 (RP2) data block with one sample (data point) for each wavelength (red, infrared). Each data point (per wavelength) is an unsigned 24-bit value represented by three bytes. The RP2 data block send order is described below. The lowest byte (Byte 0) is sent first.  Data block byte[0] byte[1] byte[2] byte[3] byte[4] byte[5] bit 23-16 bit 15-8 bit 7-0 bit 23-16 bit 15-8 bit 7-0 Red Data point Infrared Data point The time resolution of the plethysmogram is defined by the selected sample rate setting (0x1A). It can be set to 75Hz or 300 Hz sample rate The default setting is 0 Hz (off) The data samples are sent at a constant delay of: - 13.3 ms in 75Hz sample rate - 3.3 ms in the 300Hz sample rate	0 Hz (default) / 75 Hz / 300 Hz	6 Bytes	n. a.
0x08 - 0x0F	**Reserved**	-	-	-
0x10	**Response Time (RT) setting for SpO_2 and Pulse Rate** 0x00 = get current setting 0x01 = stable 0x02 = standard (default) 0x03 = sensitive 0x04 = 8-Beat averaging 0x05 = 4-Beat averaging	on request	1 Byte	1 Byte
0x11	**Reserved**	-	-	-
0x12	**Pulse Rate (PR) mode** 0x00 = get current setting 0x01 = Standard Pulse Rate (SPR) mode (default): 30 to 240 bpm 0x02 = Enhanced Pulse Rate (EPR) mode : 20 to 300 bpm	on request	1 Byte	1 Byte
0x13 - 0x16	**Reserved**	-	-	-
0x17	**Set send frequency of status information** (value at identifier 0x01) 0x00 = get current setting 0x01 = 5 Hz (default) 0x02 = 1 Hz	on request	1 Byte	1 Byte

ID	Value *(*for description to build the Host Command refer to section 2.3)*	SMARTsat®		* Host Com. Value size
		Send freq.	**Size**	
0x18	**Set Auto Scaled Plethysmogram (ASP)** 0x00 = get current setting 0x01 = ON – 15 points @ 5 Hz send frequency (default) 0x02 = OFF – 0 Hz send frequency 0x03 = ON – 1 point @ 75 Hz send frequency **Note:** Only one plethysmogram type (ASP, RP or RP2) can be activated at a time. Error 0x13 is sent, if Auto Scaled Plethysmogram (ASP) is switched on while Raw Plethysmogram (RP) / Raw Plethysmogram 2 (RP2) is activated. First switch off RP/ RP2 before switching on ASP. The current activated plethysmogram type is automatically deactivated in case RP/ RP2 is switched on.	on request	1 Byte	1 Byte
0x19	**Switch Raw Plethysmogram (RP) ON/OFF** 0x00 = get current setting 0x01 = ON - sent at selected sample rate (SR at 0x1A) 0x02 = OFF (default) - 0 Hz send frequency **Note:** Only one plethysmogram type (ASP, RP or RP2) can be activated at a time. Error 0x13 is sent, if Auto Scaled Plethysmogram (ASP) is switched on while Raw Plethysmogram (RP) / Raw Plethysmogram 2 (RP2) is activated. First switch off RP/ RP2 before switching on ASP. The current activated plethysmogram type is automatically deactivated in case RP/ RP2 is switched on.	on request	1 Byte	1 Byte
0x1A	**Set Sample Rate (SR)** 0x00 = get current setting 0x01 = 75 Hz sample rate 0x03 = 300 Hz sample rate	on request	1 Byte	1 Byte
0x1B	**Switch Raw Plethysmogram 2 for output with two wavelengths (RP2) ON/OFF** 0x00 = get current setting 0x01 = ON - sent at selected sample rate (SR at 0x1A) 0x02 = OFF (default) - 0 Hz send frequency **Note:** Only one plethysmogram type (ASP, RP or RP2) can be activated at a time. Error 0x13 is sent, if Auto Scaled Plethysmogram (ASP) is switched on while Raw Plethysmogram (RP) / Raw Plethysmogram 2 (RP2) is activated. First switch off RP/ RP2 before switching on ASP. The current activated plethysmogram type is automatically deactivated in case RP/ RP2 is switched on.	on request	1 Byte	1 Byte
0x1C	**Resolution of SpO_2 results** 0x00 = get current setting 0x01 = send results with identifier **0x04** each second (integer representation: SpO_2 results without decimal digits) 0x02 = send results with identifier **0x05** each second (float representation: SpO_2 results with 2 decimal digits)	on request	1 Byte	1 Byte

ID	**Value** *(*for description to build the Host Command refer to section 2.3)*	SMARTsat®		* Host Com. Value size
		Send freq.	**Size**	
0x1D	**Resolution of perfusion index (PI)** 0x00 = get current setting 0x01 = resolution of PI is 0.1% 0x02 = resolution of PI is 0.01% (default setting since protocol rev.12) This setting has an influence on the format of identifier 0x04. At the PI resolution of 0.1% one byte is reserved for PI. At the PI resolution of 0.01%, two bytes are reserved for PI.	on request	1 Byte	1 Byte
0x1E	**Reserved**	-	-	-
0x1F	**Request current module settings** *Byte*[0]: Response Time (RT) setting 0x01 = stable 0x02 = standard 0x03 = sensitive 0x04 = 8-Beat averaging 0x05 = 4-Beat averaging *Byte*[1]: Pulse Rate mode 0x01 = Standard Pulse Rate (SPR) mode: 30 to 240 bpm 0x02 = Enhanced Pulse Rate (EPR) mode : 20 to 300 bpm *Byte*[2]: send frequency of status information 0x01 = 5 Hz 0x02 = 1 Hz *Byte*[3]: Auto Scaled Plethysmogram (ASP) setting 0x01 = ON – 15 points @ 5 Hz send frequency 0x02 = OFF – 0 Hz send frequency 0x03 = ON – 1 point @ 75 Hz send frequency *Byte*[4]: Raw Plethysmogram (RP) ON/OFF setting 0x01 = ON - sent at selected sample rate (SR at 0x1A) 0x02 = OFF - 0 Hz send frequency *Byte*[5]: Sample Rate (SR) setting 0x01 = 75 Hz sample rate 0x02 = reserved 0x03 = 300 Hz sample rate *Byte*[6]: Raw Plethysmogram 2 with two wavelengths (RP2) ON/OFF 0x01 = ON - sent at selected sample rate (SR at 0x1A) 0x02 = OFF - 0 Hz send frequency *Byte*[7]: Resolution of SpO_2 results 0x01 = send results with identifier 0x04 each second (integer representation: SpO_2 results without decimal digits) 0x02 = send results with identifier 0x05 each second (float representation: SpO_2 results with 2 decimal digits) *Byte*[8]: Resolution of perfusion index (PI) 0x01 = resolution of PI is 0.1% 0x02 = resolution of PI is 0.01% *Byte*[9..15]: Reserved	on request	16 Bytes	0 Bytes
0x20 - 0x2F	**Reserved**	-	-	-

ID	**Value** *(*for description to build the Host Command refer to section 2.3)*	SMARTsat®		* Host Com. Value size
		Send freq.	**Size**	
0x30	**SMARTsat® Module Software Reset**	n. a	n. a.	0 Bytes
0x31	**Baud rate setting** 0x00 /0 = get current module baud rate 0x60 /96 = 9600 Bd 0x13 /19 = 19200 Bd 0x26 /38 = 38400 Bd 0x39 /57 = 57600 Bd 0x73 /115 = 115200 Bd (default) 0xE6 /230 = 230400 Bd Changing the baud rate takes approximately 1 second. NOTE: The default shipping baud rate of SMARTsat® is 115200 Bd. The host can change the baud rate. During this process the default value of 115200 Bd is overwritten by the new setting. Next time when SMARTsat® powers-up it starts with the last set baud rate setting. ℹ The baud rate can only be changed 1000 times in total.	on request	1 Byte	1 Byte

4 Examples

4.1 Change baud rate

In this example, the host changes the baud rate of SMARTsat® module from 115200 Bd to 9600 Bd:

Command from host to SMARTsat® module (at 115200 Bd)

Start flag	Channel	Identifier	Value	CRC16 Hi	CRC16 Lo	End flag
0xA8	0x10	0xB1	0x60	0x7D	0x04	0xA8

Confirmation from SMARTsat® module to host (at 115200 Bd)

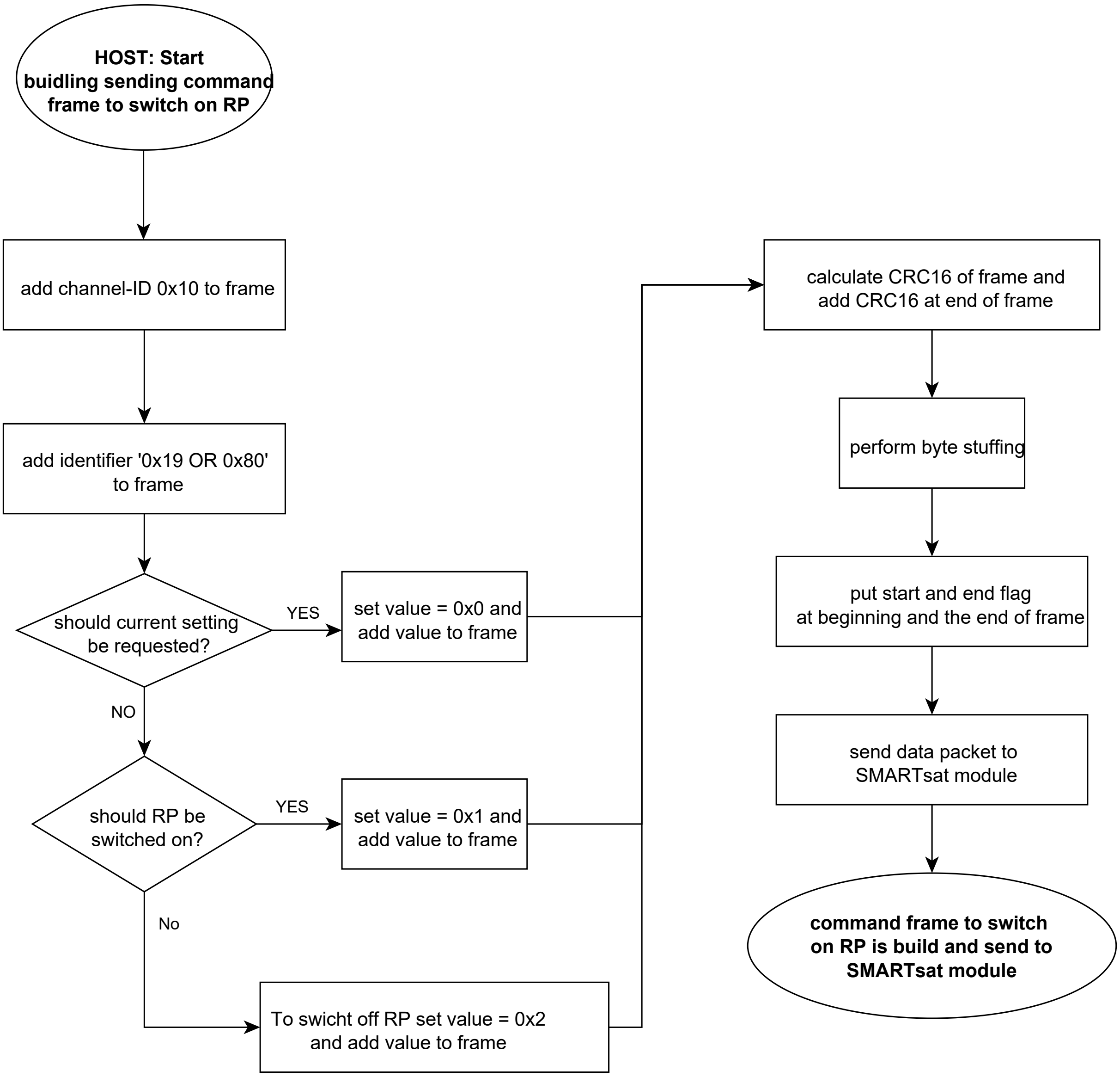
Start flag	Frame counter	Channel	Identifier	Value	CRC16 Hi	CRC16 Lo	End flag
0xA8	0x01	0x10	0x31	0x60	0xA5	0x15	0xA8

After approximately 1 second the new baud 9600 is valid.

4.2 UART send / receive in C

```
/*
The following C language functions send and receive SMARTsat® packets.
They depend on two functions, send_char() and recv_char(), which send
and receive a single character over the serial line.
*/

/* SMARTsat special character codes
*/
#define END             0xA8    /* indicates end of packet */
#define ESC             0xA9    /* indicates byte stuffing */
#define ESC_END         0x88    /* ESC ESC_END means END data byte */
#define ESC_ESC         0x89    /* ESC ESC_ESC means ESC data byte */

/* SEND_PACKET: sends a packet of length "len", starting at
* location "p".
*/
void send_packet(char *p, int len)
{

 /* send an initial END character to flush out any data that may
  * have accumulated in the receiver due to line noise
  */
        send_char(END);

 /* for each byte in the packet, send the appropriate character sequence */
   while(len--) {
           switch(*p) {
           /* if it's the same code as an END character, we send a special two character code so as not  to
make the receiver think we sent an END */
           case END:
                   send_char(ESC);
                   send_char(ESC_END);
                   break;

           /* if it's the same code as an ESC character, we send a special two character code so as not  to
make the receiver think we sent an ESC*/
           case ESC:
                   send_char(ESC);
                   send_char(ESC_ESC);
                   break;

           /* otherwise, we just send the character*/
           default:
                   send_char(*p);
           }

           p++;
   }

           /* tell the receiver that we're done sending the packet */
   send_char(END);
}

/* RECV_PACKET: receives a packet into the buffer located at "p". If more than len bytes are received, the
packet will be truncated. Returns the number of bytes stored in the buffer. */

int recv_packet(char *p, int len)
{
   char c;
   int received = 0;

   /* sit in a loop reading bytes until we put together a whole packet. Make sure not to copy them into the
packet if we run out of room. */
   while(1) {
           /* get a character to process*/
           c = recv_char();

           /* handle bytestuffing if necessary   */
           switch(c) {

           /* if it's an END character then we're done with the packet */
           case END:

/* a minor optimization: if there is no data in the packet, ignore it. This is meant to avoid bothering IP
with all the empty packets generated by the duplicate END characters which are in turn sent to try to detect
line noise. */
                   if(received)
                           return received;
                   else
                           break;

           /* if it's the same code as an ESC character, wait and get another character and then figure out
what to store in the packet based on that. */

           case ESC:
                   c = recv_char();

                   /* if "c" is not one of these two, then we have a protocol violation.  The best bet
        seems to be to leave the byte alone and just stuff it into the packet*/
                   switch(c) {
                   case ESC_END:
                           c = END;
                           break;
                   case ESC_ESC:
                           c = ESC;
                           break;
                   }

           /* here we fall into the default handler and let it store the character for us */
           default:
                   if(received < len)
                           p[received++] = c;
           }
   }
}
```

4.3 Build frame to switch on Raw Plethysmogram (RP) in C


HOST: Start buidling sending command frame to switch on RP
add channel-ID 0x10 to frame
add identifier '0x19 OR 0x80' to frame
should current setting be requested?
YES
set value = 0x0 and add value to frame
NO
should RP be switched on?
YES
set value = 0x1 and add value to frame
No
To swicht off RP set value = 0x2 and add value to frame
calculate CRC16 of frame and add CRC16 at end of frame
perform byte stuffing
put start and end flag at beginning and the end of frame
send data packet to SMARTsat module
command frame to switch on RP is build and send to SMARTsat module

```
uint32_t buildSwitchRawPlethFrame(uint8_t *fb, uint8_t rpSetting)
{
        uint16_t checkSum;
        uint8_t *p = fb;

        // Channel
        *p++ = 0x10u;

        // Identifier
        *p++ = 0x19u | 0x80u;   // Message from host to SMARTsat --> bitwise disjunction of
                                identifier and attribute 0x80

        // RP setting
        *p++ = rpSetting;

        // Checksum
        checkSum = MWData2CRC16(fb, p - fb);                    // Calculate CRC
        *p++ = (uint8_t) ((checkSum >> 8) & 0xFFu;              // High byte
        *p++ = (uint8_t) (checkSum & 0xFFu);                    // Low byte

        return (p - fb);// Return packet length
}

void switchOnRP(void)
 {
        uint8_t frameBuffer[50];
        uint8_t frameLength;

        // Build frame to switch on RP
        // 0 = get current setting, 1 = switch on RP, 2 = Switch off RP
        frameLength = (uint8_t) buildSwitchRawPlethFrame(&frameBuffer[0], 1u);

        // Add transfer layer (Start/end flag, stuffing) and send frame
        send_packet(&frameBuffer[0], frameLength);
 }
```

5 Abbreviations

Term	Description
AC/ DC	Pulsatile part of the plethysmogram / Non-Pulsatile part of the plethysmogram
ASP	Auto Scaled Plethysmogram
EPR	Enhanced Pulse Rate
IR	Infrared
n/a	not applicable
RP	Raw Plethysmogram
SR	Sample rate

6 Attachments

Attachment A1 rev.1:	Customized reserved bytes information (L)
Attachment A2 rev.2:	Customized reserved bytes information (S)

7 Revision History

Doc. Rev.	Effective Date	Prot. Rev.	Change description
16	2023-01-30	16	*Protocol changes:* - Send perfusion of Ch 0x10, ID 0x04 in two bytes (Byte[3-4]) at resolution PI 0.1% for backward compatibility with protocol rev.13 and lower. *Document changes:* - Specify data description and data range for signal quality and pulse rate (Ch0x10: ID 0x04, ID 0x05). - Update customized options per attachments A2
15	2023-01-19	15	*Protocol changes:* - Add identifier 0x1F (Request all current module settings) - Add customised module settings of identifier 0x1F per updated A1, A2 *Document changes:* - Section 3.1 maximum byte length added for each ID - Add warning in section 3.1 (ID 0x06) - Correct Ear probe sensor ID to 0x0033 (channel 0x10 ID 0x06)
14	2022-12-19	14	*Protocol changes:* - Add ASP with 1 data point at 75 Hz, see Ch 10, ID 0x02, 2) - Add identifier 0x1D (resolution of perfusion index in results identifier 0x04) to regain backward compatibility - Add functionality of reserved identifier 0x08 and 0x1E of Channel 0x10 to customized Protocol Attachment A1 *Document changes:* - Add customized options per attachments A1 and A2. - Rework description of RP2 (Ch 0x10, ID 0x07) - Rename Results Options (ID 0x04, 0x05) - Add sections 2.2.5 and update 2.3.3. Rework chapter hierarchy.
13	2022-05-06	13	- Add identifier 0x05 (Float SpO2 results) - Add identifier 0x07 (Raw Plethysmogram output of two wave length) - Add identifier 0x1B (Switch Raw Plethysmogram output of two wave length (RP2) ON/OFF) - Add identifier 0x1C (Result output switch between identifier 0x04 and 0x05)
12	2022-03-14	12	Change resolution of the perfusion index (PI) from 0.1% to 0.01% (Ch 0x10, ID 0x04) **NOTE: this version is not backward compatible.**
11	2020-04-17	11	- Replace 150Hz sample rate by 300Hz sample rate (robust performance also at ripple on power supply) - rename “finger out”, to be “probe off” (status applies also to ear sensors) - update example in section 3 - Rework layout and format, , add document number
10	2019-10-16	10	- Add flowcharts and images to support understanding dataflow and structure. - Remove HRP mode (0x11) and replace with Raw Plethysmogram (RP), were applicable. - update example in section 6.3 - rename “pulsation strength” to be “perfusion index” - correct “undefined sensor” to 0xFFFF (before 0x00FF)
9	2017-06-29	9	*Changes only available for OEM I and II:* - Add Identifier 0x19 (Switch High Resolution Plethysmogram ON/OFF) - Add Identifier 0x1A (Set sample rate)
8	2017-01-31	8	- Add Identifier 0x0A (Sensor Error: Short circuit) to Error channel. Measurement is interrupted and error is sent together with “sensor defective status” if SMARTsat detects short at sensor LED. (Before measurement was interrupted and status “sensor defective” was sent).
7 - A	2016-09-06	7	*Note: change to document, communication protocol unchanged* - corrected typos - Add description to error channel (section 2)
7	2016-08-24	7	- Add Identifier 0x06 in Common device channel 0x01 - Add Identifiers 0x07, 0x08, 0x09 and 0x13 in Error channel 0x02 - Add Bit 7 at Identifier 0x01 of SMARTsat® channel 0x10 - Add Bit 7 at Byte 6 of Identifier 0x04 in SMARTsat® channel 0x10 - Update the Sensor Type ID (backward compatible)

Doc. Rev.	Effective Date	Prot. Rev.	Change description
			- Add information that HRP needs to be switched off before auto scaled pleth can be switched on again - update examples in HEX
6	2016-03-14	6	*Note: change to document, communication protocol unchanged* - Add description on how commands are send by host (section 2.3) - Add examples in HEX at “Common device channel”, “Error channel” - Add examples in C for “UART send/receive” and “build frame to switch on HRP”
5	2016-03-08	5	*Add Features:* - send single HRP data samples (3 Byte, before 45 Byte) - switch Auto scaled plethysmogram (ID 0x02) on/off - transmission frequency of status selectable from 5Hz to 1Hz - remove sending ID 0x10,0x12 at 1Hz, add sending these settings at ID 0x04,
4	2016-03-03	4	*Note: change to document, communication protocol unchanged* - Rename section 1, 2, 3, headers of tables - Add 1.1 Data link layer, add 1.2 Data package structure - Change images at “Auto scaled plethysmogram”, “HRP” - Add HEX values (not only decimal) to table under SMARTsat® channel
3	2016-02-19	3	*Note: change to document, communication protocol unchanged* - Changed: Format, length and examples for common device channel 0x01 - Add: HRP data send order, Pulse beep pointer bit positions, SpO2 send order, Status send order, Sensor type send order
2	2015-12-08	2	- Combined version for SMARTsat® OEM I – III (based on MW Protocol rev.2) - Removed: electrical properties of serial interface (part of Integration Guide) - Add: EPR 150 Hz, 300 Hz, example for destuffing, sensor types
1	2014-12-19	1	First version for Integration Guide based on MW Protocol rev. 1
0	2014-12-15	0	Initial version