

SMARTsat® OEM I/ II/ III

Integration Guide



MODULE SPECIFICATION AND TECHNICAL INFORMATION

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.

SMARTsat® Integration Guide

Document number: O-07-00-001

Document revision: 10

Released: 03/2022

MODULE SPECIFICATION AND TECHNICAL INFORMATION IS VALID FOR THE FOLLOWING HW AND SW VERSIONS:

Part number (REF)	Module	Hardware (HW)	Software (SW)	Host Protocol
8110502001	SMARTsat® OEM I	V1.4 REV.5A V1.4.1 REV 5A	BM.01.A17.A25.1S BM.01.A18.A25.1S	Rev.12
9110100001	SMARTsat® OEM II	V3.0 REV A V3.1 REV A	BM.07.A17.A25.1S BM.07.A18.A25.1S	Rev.12
8110140011	SMARTsat® OEM III	V3.3.1_Rev.B	BM.03.B37.A24.1B	Rev.12

The information in this document is subject to change.

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

Copyright © 2014 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: www.bluepoint-medical.com

Liability

bluepoint MEDICAL GmbH & Co. KG shall in no event be liable for any direct, indirect, special or consequential damages including without limitation damages for loss of business profits, loss of income, business interruption, loss of business information, loss of use or other related exposures, however caused, arising from the faulty or incorrect use of the product.

bluepoint MEDICAL GmbH & Co. KG guarantees that the product delivered has been thoroughly tested to ensure that it meets its published specifications.

Warranty

bluepoint MEDICAL GmbH & Co. KG warrants the products manufactured or distributed by them to be free from faulty materials and workmanship for a period of 24 months from date of original shipment to first end user except for disposable products or products which have a stated guarantee longer or shorter than 24 months. bluepoint MEDICAL GmbH & Co. KG will perform warranty service at its factory.

The obligations for bluepoint MEDICAL GmbH & Co. KG under this guarantee shall be limited to repair, or at bluepoint MEDICAL GmbH & Co. KG's discretion, replacement of necessary parts or assemblies and shall not include shipping costs or other incidental damages.

Claims for damages during shipment must be filed promptly with the transportation company. All correspondence concerning the products must specify both the name of the product and its serial number as written on the label on the product.

Use of the equipment for other than its intended use, or if it has been repaired by anyone except bluepoint MEDICAL GmbH & Co. KG or a bluepoint MEDICAL GmbH & Co. KG authorized service center or altered or modified or used without following the instructions in the user manual, will void this guarantee.

Trademarks

bluepoint MEDICAL GmbH & Co. KG owns the following registered trademarks:

SMARTsat®, Rubber boot®, SoftCap®, SoftFlap® and SoftWrap®

Table of Contents

1	INTRODUCTION	6
1.1	OVERVIEW AND INTENDED USE	6
1.2	REFERENCES	8
1.3	TERMS AND DEFINITIONS	8
1.4	SYMBOLS	9
1.5	SAFETY INFORMATION	10
1.5.1	<i>Warnings</i>	10
1.5.2	<i>Contraindications</i>	12
2	FEATURES AND PERFORMANCE	12
2.1	SPO ₂ AND PULSE RATE MEASUREMENT ACCURACY	12
2.2	MEASUREMENT MODES	15
2.2.1	<i>Enhanced Pulse Rate Mode (EPR)</i>	15
2.2.2	<i>Response Time Setting</i>	15
2.2.3	<i>Raw Plethysmogram (RP)</i>	16
2.3	STATUS FLAGS	17
2.4	ERROR CHANNEL	18
2.5	CIRCUMSTANCES THAT CAN INFLUENCE THE MEASUREMENT	18
3	GUIDELINES FOR INTEGRATION	19
3.1	SMARTSAT® OEM I	19
3.1.1	<i>Physical dimensions</i>	19
3.1.2	<i>Electrical interface</i>	20
3.2	SMARTSAT® OEM II AND III	21
3.2.1	<i>Physical dimensions</i>	21
3.2.2	<i>Electrical interface</i>	22
3.3	EXTERNAL SMARTSAT® EB	24
3.3.1	<i>Physical dimensions</i>	24
3.3.2	<i>Electrical interface</i>	24
3.4	SPO ₂ SENSOR CONNECTION OPTIONS	25
3.4.1	<i>SpO₂ sensor plug – 6 pin minimed</i>	25
3.4.2	<i>SMARTsat® SpO₂ sensor basic flex</i>	26
3.4.3	<i>SMARTsat® SpO₂ sensor low noise flex</i>	27
3.4.4	<i>SMARTsat® SpO₂ sensor low noise flex – OEM I</i>	28
4	HOST SYSTEM CONSIDERATIONS	28
4.1	POWER SUPPLY REQUIREMENTS	28
4.1.1	<i>Power consumption and sampling rate</i>	29
4.1.2	<i>Power consumption and baud rate</i>	29
4.2	POWER-ON INITIALIZATION AND SELF-TEST	29
4.3	RESET	29
4.4	SHIELDING/ CROSSTALK	30
4.5	ELECTROSTATIC DISCHARGE (ESD) PROTECTION	30
4.6	ELECTROMAGNETIC COMPATIBILITY	30
4.7	PATIENT ISOLATION REQUIREMENTS	30
4.8	PRODUCT STANDARDS	31
5	HOST COMMUNICATION	31
5.1	INTERFACE SPECIFICATION	31
5.2	ELECTRICAL PROPERTIES RX/TX FOR	31
5.2.1	<i>SMARTsat® OEM II and III</i>	31
5.2.2	<i>SMARTsat® OEM I</i>	31
5.3	BAUD RATE CONFIGURATION	31
6	DEVELOPMENT KIT	32
6.1	SMARTSAT® DEVELOPMENT BOARD	33

6.2	SMARTSAT® PROTOCOL VIEWER AND EMULATOR	36
6.3	SMARTSAT® PROTOCOL EMULATOR	37
6.4	COMMUNICATION PROTOCOL VERIFICATION PROCEDURE.....	39
7	TECHNICAL DATA	40
8	ORDER NUMBERS	43
8.1	DEVELOPMENT KITS, MODULES AND CONNECTORS	43
8.2	SENSORS AND ACCESSORIES	44
9	REPORTING OF SERIOUS INCIDENTS	44
10	REVISION HISTORY	45

1 Introduction

1.1 Overview and intended use

The bluepoint MEDICAL SMARTsat® pulse oximetry module is a small printed circuit board assembly with the new SMARTsat® technology for non-invasive and continuous measurement of functional oxygen saturation in arterial blood (SpO₂) and pulse rate (PR) of adults, pediatrics, infants and neonates.

SMARTsat® is intended to be used in following application areas; considering safety instructions:

- **Professional health care facility environment** like pre- und postoperative monitoring, anesthesia, intensive care units (ICU), sleep medicine, pulmonology and sports medicine
- **Transport and home health care environment** like emergency medicine, ambulance service and home monitoring

The SMARTsat® boards are small low power pulse oximetry modules, designed for OEM use and support the full range of bluepoint MEDICAL SMARTsat® pulse oximeter sensors as SoftCap®, SoftFlap®, SoftWrap®, Earprobe and disposable sensors in different sizes (see section 8.2).

The SMARTsat® technology provides a motion tolerant algorithm to measure SpO₂ and pulse rate under low perfusion and motion conditions. The sensors, depending on type, are applied to various parts of the patient's body (e.g. finger, ear, neonatal foot). See the respective sensor instructions for use for more information.

Available SMARTsat® boards are listed in the table below.

Module	Part Number (REF)	Description
SMARTsat® OEM I	8110502001xx	Low perfusion performance and motion tolerant, active ambient light compensation (AAC), equipped with EMI filter for optional direct sensor connection
SMARTsat® OEM II	9110100001xx	compact, low perfusion performance and motion tolerant, active ambient light compensation (AAC)
SMARTsat® OEM III	8110140011xx	compact, motion tolerant and low power
SMARTsat® EB	On request	external housing with SMARTsat® OEM II or OEM III

xx: Indicates customized FW versions (e.g. customized start-up settings / sensor coding)



Fig. 1-1: SMARTsat® OEM I (left), OEM II (middle) OEM III (right)

As alternative to the internal SMARTsat® module, the external SMARTsat® EB can be used with integrated SMARTsat® OEM II or OEM III. It allows an easy connection to a host system via USB or UART.



Fig. 1-2: External SMARTsat® EB

The following parameters are available via the Host Interface:

- Functional arterial oxygen saturation (SpO₂)
- Pulse rate
- Normalized pulse waveform and perfusion index (based on 905 nm)
- Signal quality indicator
- Pulse search indicator
- Interference indicator
- Sensor disconnect indicator
- Probe off patient indicator
- Loss of pulse indicator

By default the normalized pulse waveform, the **Auto Scaled Plethysmogram (ASP)** sampled at 75 Hz, is send to the host. The waveform is automatically adjusted to the pulse strength; therefore, a waveform of good amplitude should be visible at all times. The host system may correlate the waveform reading with the perfusion index to reflect the signals condition.

For applications which calculate the PTT (Pulse Transit Time) however, activation of the raw plethysmogram (RP) at 300Hz sample rate is recommended.

Note: Upon activation of the raw plethysmogram (RP), a minimum baud rate of 115200 Bd is required.

SMARTsat® OEM modules communicate with a host system via a serial communication interface. The detailed protocol and the electrical interface are described in this integration guide and in a separate document SMARTsat® Communication Protocol [1].

The figure below presents a schematic of the integration of SMARTsat® into a host system.

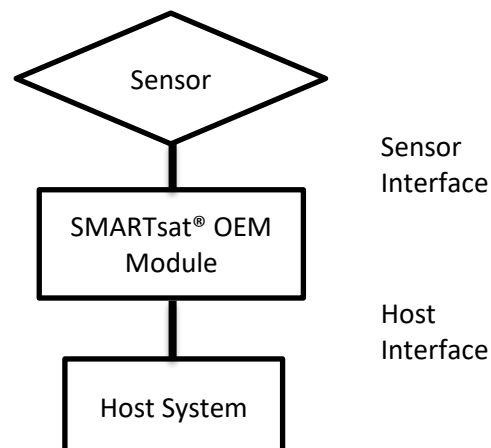


Fig. 1-3: SMARTsat® integration into a host system











1.2 References

ID.	Document number	Description / Title	Rev.
[1]	O-07-00-002	SMARTsat® Communication Protocol – SMARTsat® OEM III	12
[2]	O-07-00-003	SMARTsat® I-III Host Validation Checklist	3

1.3 Terms and definitions

Item	Description
AAC	Active Ambient light Compensation
AM	Alarm monitor
Appl.	Application
ASP	Normalized Auto Scaled Plethysmogram
BPM	Beats per minute
CM	Continues measurement
CO	Carbon monoxide
COHb	Carboxyhemoglobin
EMC	Electro magnetical compatibility
ESD	Electrostatic discharge
EUT	Equipment under test
HW	Hardware
HI	Host interface
HRP	High Resolution Plethysmogram Mode, a feature in Host Protocol rev.8 [1]
IFU	Instructions for Use
IMPL	Implemented
MetHb	Methemoglobin
MDR	Medical Device Regulation 2017/745
Plethysmogram	Sensor signal waveform of the absorption of light (wavelength 905 nm) at the measurement site reflecting the relative pulsation strength.
PI	Perfusion index (PI) is the ration of the pulsatile infrared part of the plethysmogram (AC)/ Non-Pulsatile part (DC). It represents the pulsation strength (blood circulation) at the measurement site and is an indicator for good signal quality if > 1%.
PR	Pulse rate
PTT	Pulse Transit Time
RP	Raw Plethysmogram
SpC	Spot check measurement
SpO2	Oxygen saturation
SW	Software

1.4 Symbols

Symbol	Description
	Accompanied with “ Warning: <i>Supplementary text.</i> ” within this document. Warnings indicate potential harmful conditions that may lead to injury or death.
	Accompanied with “ Caution: <i>Supplementary text.</i> ” within this document. Cautions indicate conditions that may lead to damage to or malfunction of the device.
Note:	Denoted as “ Note: <i>Supplementary text.</i> ” within this document. Notes inform the user to relevant facts and conditions in connection with the device.
	Consult User Manual for detailed operating information.
	Manufacturer
	Date of manufacture
	Type BF applied part
REF	Catalogue number
SN	Serial number
	Storage temperature limitation
	Storage humidity limitation
	Fragile, handle with care
	Do not dispose in the consumer waste. Electrical and electronic equipment shall be collected and recycled in accordance with (Directive 2002/96/EC)

1.5 Safety information

1.5.1 Warnings

SMARTsat® has been developed to meet the requirements of the standards listed in section 4.8 as applicable. All corresponding standards are to be taken into consideration during integration in a host system. Any influences on or from the host system are not considered.

Warnings in connection with the integration and use of SMARTsat® are listed below. In addition, consult the additional warnings listed in the instructions for use provided together with the specific SpO₂ sensor.



Warning:

These user instructions are a component of SMARTsat®. SMARTsat® should only be used for the purpose and in the manner described in this manual.



Warning:

SMARTsat® is designed and tested within the described operating parameters. Changes of the conditions and parameters may lead to faulty measurements or damage the module.



Warning:

SMARTsat® and all accessories may only be used by persons with sufficient expertise.



Warning:

SMARTsat® is only to be integrated in a host system and operated by qualified personnel.



Warning:

ESD protection for the SMARTsat® boards should be provided by the host system. The SMARTsat® boards contain static sensitive devices and therefore should itself be treated as a static sensitive device. The module is not defibrillator proof.



Warning:

There is no patient isolation on the SMARTsat® boards. The host system must provide electrical isolation for all connections to the module to meet the requirements of EN 60601-1 medical electrical equipment safety requirements and other electrical safety specifications as applicable. The sensor isolation must not be considered when evaluating patient isolation. The silicon layers on the LEDs and receiver do not qualify as insulation, since they can be damaged if not used as intended.



Warning:

For the SpO₂ measurement, the monitor uses red and infrared light with specific fixed wavelengths. Consider that these wavelengths might influence diagnostic parameters of other optical applications. The specifications of the wavelengths used are listed in the 'Instructions for Use' of the specific sensor.



Warning:

Certain environmental and physiological conditions, medical procedures, sensor application errors and external agents may interfere with the ability of SMARTsat® to detect and display accurate measurements (section 2.5 provides information on possible interferences).



Warning:

SMARTsat® can show faulty measurements or can be damaged if it will be used outside the specification or environmental conditions.



Warning:

SMARTsat® may not be submerged in liquids, have liquids poured on it or be cleaned with liquid detergents. SMARTsat® should be protected from condensation and humidity.



Warning:

Do not apply excessive tension to any of the monitor cables.



Warning:

Any radio frequency transmitting equipment or other nearby sources of electrical noise may result in disruption of the monitoring system.



Warning:

Use of this equipment adjacent to or stacked with other equipment should be avoided because it could result in improper operation. If such use is necessary, this equipment and the other equipment should be observed to verify that they are operating normally.



Warning:

Portable radio frequency communications equipment (including peripherals such as antenna cables and external antennas) should be used no closer than 30cm (12 inches) to any part of the host monitor, including cables specified by the manufacturer. Otherwise, degradation of the performance of this equipment could result.



Warning:

The use of accessories, sensors, and cables other than those specified or provided by bluepoint Medical could result in increased electromagnetic emission or decreased electromagnetic immunity of this equipment and result in improper operation.



Warning:

Only pulse oximeter accessories, sensors, and cables offered by bluepoint Medical and listed in the SMARTsat® compatibility list may be used together with SMARTsat® integrated in a host monitor. Sensors and accessories must be in undamaged condition. If other sensors and accessories are used, it could lead to malfunctions, problems with biocompatibility and create invalid readings. The operator is responsible for checking compatibility prior to use.



Warning:

Do not use sensors, cables or lines that appear to be damaged by transport or other means. Do not use sensors when optical components are exposed. Do not use a sensor or cable that appears damaged. Replace it immediately in cases of visible damage.



Warning:

Always disconnect the monitor and probes from the patient during magnetic resonance imaging (MRI) scanning. An induced current could potentially cause burns.



Warning:

Disconnect the sensor from the patient throughout computed tomography, as during the active irradiation period, the reading might be inaccurate.



Warning:

Do not autoclave or steam sterilize the SMARTsat® or its accessories. Refer to the specific 'Instructions for Use' of the used SpO₂ sensor for correct cleaning and/or sterilization.



Warning:

If you are uncertain about the accuracy of any measurement, check the patient's vital signs by alternative means, then ensure that the SMARTsat® is functioning correctly.



Warning:

To prevent damage, avoid undue bending of the sensor cable.

**Warning:**

A functional tester (like Index II or equivalent) may not be used to validate SpO₂ accuracy. A functional tester can be used to verify the function of pulse oximeter probes.

1.5.2 Contraindications

There are no known contraindications to the use of the device.

2 Features and performance

2.1 SpO₂ and pulse rate measurement accuracy

The SMARTsat® boards and SMARTsat® SpO₂ sensors are designed to meet the accuracy requirements in accordance with ISO 80601-2-61.

According to this standard, the approved pulse oximetry sensors are calibrated and evaluated against invasive references determined by a CO oximeter. The functional and fractional oxygen saturation was identical, which means that dyshemoglobin derivatives as carboxyhemoglobin or methemoglobin were not present. Due to this method, a falsification of the reference caused by dysfunctional hemoglobin fractions can be eliminated.

SMARTsat® has been clinically validated within the range of 60 % - 100 % SpO₂. The clinical accuracy claims are listed in the table below.

Table 1: Accuracy claims - SMARTsat® OEM I/ II / III

Parameter	Measurement range	Accuracy
SpO ₂ (Functional oxygen saturation)	0 – 100 %	70 – 100 %: $A_{rms} \leq 2\%$ (no motion, incl. low perfusion ³) ^{1, 4}
		60 – 80 % : $A_{rms} \leq 2\%$ (no motion, incl. low perfusion ³) ^{1, 4}
		70 – 100 %: $A_{rms} \leq 3\%$ (motion condition) ²
		<60%: unspecified
Pulse Rate	Standard Mode: 30 – 240 bpm	$A_{rms} \leq 2\text{bpm}$ (no motion, incl. low perfusion ³) ⁵
	Enhanced Pulse Rate Mode (EPR): 20 – 300 bpm	$A_{rms} \leq 3\text{bpm}$ (motion condition ²)

¹⁾ Because pulse oximeter measurements are statistically distributed, only about two-thirds of measurements can be expected to fall within $\pm A_{rms}$ of the measured values by a co-oximeter.

²⁾ Tested with all Fluke Index II Oximeter tester motion patterns with pattern specific motion frequency of 0.5Hz to 6Hz at perfusion PI: 0.65% to 5% including non-repetitive motion and motion repeating every 0.5Hz.

³⁾ Tested with Fluke ProSim 8 Oximeter tester at infrared percentage modulation PI: 0.7% to 0.1%

⁴⁾ Applies to reusable SMARTsat® sensors, refer to sensor instructions for use for sensor specific accuracy claims

⁵⁾ Tested with Fluke ProSim 8 Oximeter tester throughout the pulse rate range of 20 – 300bpm

The SMARTsat® pulse rate range and low perfusion capability was validated with the Fluke ProSim 8 vital sign simulator. The pulse rate und SpO₂ accuracy under motion was tested with the Index II SpO₂ simulator at standard response time mode and standard pulse rate mode.

To validate the SpO₂, accuracy-controlled hypoxia studies were conducted on a pool of consenting subject volunteers at an independent research laboratory. The pool consists of 12 subjects (4 female and 8 male) aged 21 to 32 years.

All subjects were healthy, non-smoking, light-to-dark-skinned and without anemia. Equally distributed in the range of 60 % – 100 % the measured SpO₂ values of the sensors are compared to SaO₂ values of drawn blood samples measured by a CO-oximeter. Accuracy data is calculated using the root-mean-squared (A_{rms} value) for all subjects, per ISO 80601-2-61. The clinical accuracy testing verifies that the bluepoint MEDICAL SMARTsat® Pulse Oximeter Technology in combination with the following SMARTsat® SpO₂ sensors, demonstrated clinical accuracy performance consistent with the requirements of the applicable international standard criteria for accuracy:

SoftCap® (SC7500), SoftFlap® (SF7500), SoftWrap® (W7500), Disposable Adult® (10-AP), Disposable Neonate (10-NP), Disposable Pediatric (10-PP), Disposable Infant (10-IP) and Ear Probe (EP7500).

Modified Bland and Altman plots (SpO₂ - SaO₂) versus SaO₂ for each combination of representative SpO₂ sensor are listed in the sensor specific instructions for use. Those plots show the data for all subjects pooled, including upper 95 % and lower 95 % limits of agreement.

The table below presents the detailed measurement results of the study for each representative sensor respectively.

Table 2: Clinical SpO₂ accuracy validation results - SMARTsat® OEM I/II

Sensor type	A_{rms} SpO ₂ [%] by SaO ₂ -Rang ³⁾				
	70–100 %	90–100 %	80–90 %	70–80 %	60-70%
SC7500 ¹⁾	1.6	1.1	1.7	1.8	1.9
SF7500	1.5	1.4	1.3	1.7	2.3
W7500	1.4	1.0	1.2	1.8	2.8
EP7500	2.1	1.0	1.7	2.8	3.5
10-AP ²⁾	2.1	2.2	1.9	2.0	2.2

¹⁾ Results apply to equivalent sensors SCM7500 and SCP7500

²⁾ Results apply to equivalent sensors 10-PP, 10-IP, 10-NP

³⁾ Validation performed with SMARTsat® OEM II integrated in the bluepoint Medical CapnoTrue® multi-parameter monitor

Table 3: Clinical SpO₂ accuracy validation results – SMARTsat® OEM III

Sensor type	A_{rms} SpO ₂ [%] by SaO ₂ -Rang ^{c)}				
	70–100 %	90–100 %	80–90 %	70–80 %	60-70%
SC7500 ^{a)}	1.6	1.5	1.8	1.7	2.4
SF7500	1.5	1.4	1.4	1.7	2.0
W7500	1.6	1.3	1.5	1.9	2.4
EP7500	1.8	1.4	1.7	2.3	3.3
10-AP	2.4	2.1	2.3	2.6	3.4
10-PP ^{b)}	2.3	2.6	2.4	1.7	1.9
10-NP	1.9	1.7	1.6	2.3	2.9

^{a)} Results apply to equivalent sensors SCM7500 and SCP7500

^{b)} Results apply to equivalent sensor 10-IP

^{c)} Validation performed with SMARTsat® OEM III integrated in the bluepoint Medical OxyTrue®A pulse oximeter monitor

The table below presents the detailed motion performance results of the SMARTsat® at standard response time mode and enhanced pulse rate mode.

Table 4: SMARTsat® performance under motions tested with FLUKE Index II SpO₂ simulator

Fluke Index II SpO ₂ simulator settings					Accuracy SMARTsat® OEM III ⁽¹⁾	
Motion pattern	PI [%]	Motion Freq. [Hz]	SpO ₂ [%]	Pulse rate [bpm]	SpO ₂ [A _{rms}]	Pulse rate [A _{rms}]
1. Normal	5.00	-	98	55	0	0
2. Weak	0.65	-	90	95	0.5	0
3. Bradycardia	5.00	-	88	45	0.4	0
4. Hypoxic	2.00	-	70	95	0.3	0
5. Neonate	1.00	-	90	180	0.6	0
6. Tachycardia	1.20	-	85	130	0.4	0
7. Geriatric	2.40	-	92	95	0.4	0
8. Obese	3.00	-	93	90	0.4	0
Pooled Arms for medical conditions #1 to #8:					0.4	0
10. Normal/Tap	5.00	2.5	98	55	0.4	1
11. Normal/Shiver	5.00	6.0	98	55	0.6	1
12. Weak/Tap	0.65	4.3	90	95	0.4	0
13. Weak/Shiver	0.65	6.0	90	95	0.9	1,1
14. Brachy/Shiver	5.00	6.0	88	45	0	1
15. Hypoxic/Tap	2.00	4.3	70	95	0	0
16. Hypoxic/Shiver	2.00	6.0	70	95	0.4	0.7
17. Neonate/Shiver	1.00	6.0	90	180	4	0
18. BradyTap#2	5.00	3.9	88	45	0.7	0.9
19. HypoxTap#2	2.00	4.3	70	95	0.9	1.4
20. WeakTap#2	0.90	1.0	80	95	0.7	1.7
21. NormalTap#2	5.00	2.5	93	55	0.8	0.9
22. Asystole ⁽²⁾	2.00	1.1	0	0	0	0
23. LowFreq1	1.00	0.5	80	75	0.9	0.8
24. LowFreq2	1.00	0.5	70	75	1.7	0.7
25. SlowTap	1.00	2.0	80	75	2.8	2.2
Pooled Arms for medical conditions #9 to #24:					1.4	1.1

⁽¹⁾ Results for OEM I/ II/ III are equivalent based on SW design. Test performed in enhanced pulse range mode (EPR ON), standard response time mode, 75Hz sampling rate and with the SC7500 SpO₂ sensor. Changing the Response Time Settings has significant influence on motion tolerance performance (see section 2.2.2, table 5).

⁽²⁾ Result taken during the Asystole. In case cardiac massage is performed thereafter, the measurement results present the true saturation value and the heart rate represents the cardiac massage rate.

2.2 Measurement modes

2.2.1 Enhanced Pulse Rate Mode (EPR)

SMARTsat® offers a *standard* and *enhanced pulse rate (EPR)* mode.

The *standard pulse rate mode* offers a pulse rate measurement range of 30 – 240 bpm (beats per minute). By selecting the *enhanced pulse rate mode (EPR)* the pulse rate measurement range is significantly increased to 300 bpm. This mode is typically used in veterinary applications.

Both modes show high motion tolerance performance depending on the response time mode setting selected (see section 2.2.2, table 5).

2.2.2 Response Time Setting

Five different response time settings are available for selection depending on the application. The figure below presents the time response for all possible response time modes at set pulse rate of 75 bpm. After a stable baseline of 20 seconds the SpO₂ reference drops from 97 % down to 70 % within 36 seconds which corresponds to a slope of -0.75 %/ sec. Within 15 seconds the SpO₂ value increases back to 97 % which correspond to a slope of 1.8 %/ sec.

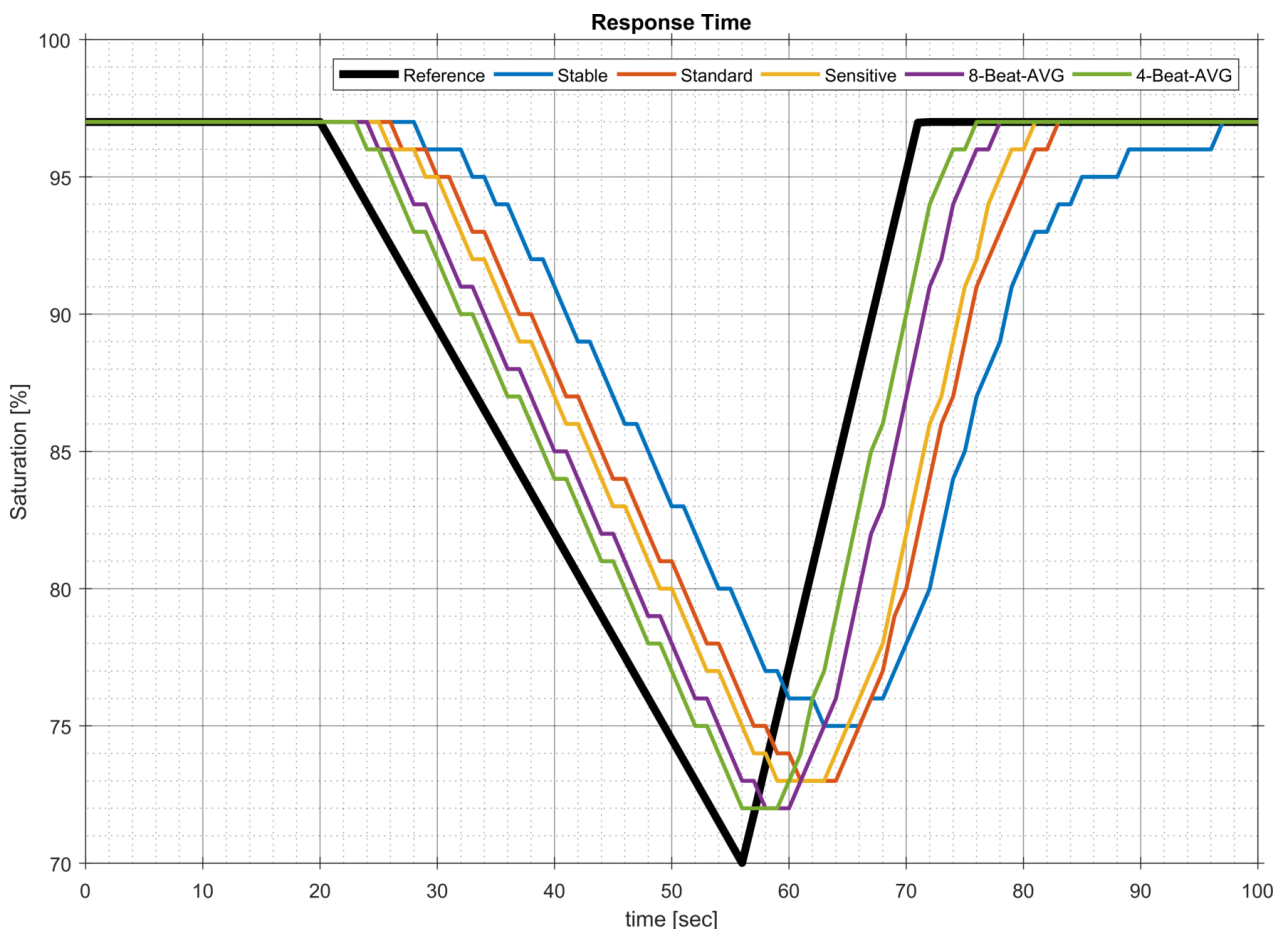


Fig. 2-1: SMARTsat® SpO₂ response time diagram

Changing the response time mode has influence on the time delay of displayed SpO₂ and pulse rate measurement values.

Note: Motion tolerance performance is significantly reduced for modes with short response time (8-Beat averaging, 4-Beat averaging). Table 5 presents the available modes listed in motion tolerance categories.

In a similar way the response time of the pulse rate is determined. After a stable baseline of 20 seconds the pulse rate reference increases from 20 bpm up to 300 bpm at 0.5 bpm/ sec. The average response time at a pulse rate of 75 bpm is listed in the table below.

Table 5: Average response time for each response time mode (refer to Fig. 2-1)

Response Time Mode	Motion tolerance performance	Average response time	
		SpO ₂ (see Fig 2-1)	Pulse rate (@75bpm)
Stable	highly motion resistant	12 sec	12 sec
Standard (default)	motion resistant	8 sec	10 sec
Sensitive	reduced motion resistance	7 sec	8 sec
8-Beat averaging	no motion resistance	4 sec	5 sec
4-Beat averaging	no motion resistance	3 sec	4 sec

SpO₂ and pulse rate values are calculated and updated continuously during measurement and averaged according to the selected Response Time Setting. In case of heavy signal distortion (motion artefacts, electromagnetic interference, low perfusion), the last valid value is transmitted. If the distortion continues for longer than the maximal Data Update Period, the data output of SpO₂ and pulse rate are set to “no valid value” (output = 0xFF).

NOTE: The maximal Data Update Period is 28 sec in all measurement modes.

2.2.3 Raw Plethysmogram (RP)

The Raw Plethysmogram (RP) is an optional feature which can be activated at all Response Time Settings and allows the output of a high resolution plethysmogram at the selected sampling rate. This plethysmogram is not normalized.

This mode is typically used by a host to calculate the PTT (Pulse Transit Time) based on additional designated host signals.

Note that due to the high sampling rate the RP mode requires a minimum baud rate of 115200 Bd or larger and the total power consumption of the board is increased.

In case the actual used baud rate is below 115200 Bd the RP is blocked and the host has to increase the baud rate to enable the feature. The RP is available at both samples rates: 75 Hz and 300 Hz. For switching the plethysmogram and the sampling rate see document SMARTsat® Communication Protocol [1].

2.3 Status flags

The SMARTsat® continuously monitors the sensor and physiological conditions and reports the status (refer to [1]) Status flags include:

Status Information	Reason
Sensor disconnected	Sensor is not connected
Probe off	Sensor has been removed from the measurement site or slipped of the measurement site (finger or ear lobe)
Searching for pulse	No pulse detected in the signal. This could be due to no pulse present or artefacts in the signal.
Pulse searching longer than 30 sec	No pulse detected for longer than 30 seconds. This could be due to no pulse present or artefacts in the signal. No SpO ₂ or pulse rate values are transmitted.
Loss of pulse	No pulse is detected and therefore 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.
Low perfusion index (low AC/DC ratio)	The perfusion index (PI) is below 1 %. PI = AC/ DC ratio of wavelength 905 nm. Low perfusion conditions are typical e.g. during patient shock conditions and cold hands.
Low transmission	The sensor signal is very small. Low signal transmission can occur if the absorption between LED and detector is large e.g. measurement at a neonatal foot or a dark thick finger.
Interferences detected	Interferences degrade signal quality and potentially cause incorrect measurement values e.g. electromagnetic or electrosurgical interference source.
Motion artefacts	Motion artefacts degrade signal quality and potentially result in wrong measurement values. This condition occurs during e.g. excessive motion at sensor site or moving the finger inside the sensor head.
Vital parameter out of range	Measurement values are invalid because they are outside the specified measurement range. Possible reasons are the use of intravascular dyes.
Supply voltage out of range	The supply voltage provided to the module is outside of the specified range. Under these conditions the measurement values are potentially incorrect.
Ambient light	Ambient light level exceeds the limit of possible compensation. The measurement is interrupted and the flag is sent.
Sensor defective	The sensor, its cable or the optical components are defective. The measurement is interrupted. Remove the sensor to reset the flag. Measurement is continued on connection of a new sensor.
Wrong sensor	The connected SpO ₂ sensor is not compatible with the SMARTsat® board. The connected sensor could result in wrong measurement values or electrical hazard to the patient.

2.4 Error channel

The SMARTsat® continuously monitors the functionality of software and hardware components. In case an error is detected the error message is send instantly via the error channel as long as the error condition is present at 1Hz. Error status includes e.g. Frame corrupt, CRC error, Buffer overflow etc. (refer to [1]).

2.5 Circumstances that can influence the measurement

Physiological conditions, medical procedures, or external agents that may degrade pulse oximeter performance or affect the accuracy of the measurement include the following:

Ambient light:

If the ambient light level exceeds a limit of compensation SMARTsat® interrupts the measurement and sends out the status flag “Ambient light”.



Shield the SpO2 sensor application site with opaque material if the measurement is interrupted and the status flag “Ambient light” is send

Motion artefacts:

The SMARTsat® algorithm suppresses the influence of motion on the SpO₂ and PR measurement (see section 2.1). However long and continuous motion can lead to wrong measurements. SMARTsat® provides a Signal Quality and Motion indicator to inform the user if the measurement value is potentially incorrect.



Check the sensor site and prevent motion artefacts if SMARTsat® detects bad signal quality, motion artefacts, interferences etc. (see SMARTsat® status flags)

Dysfunctional hemoglobin (e.g. COHb, MetHb):

High concentration of dysfunctional hemoglobin which is not able to transport oxygen, as COHb or MetHb, can falsify the measurement. The indicated result seems to be normal but the patient can be hypoxic.

Intravascular dyes:

Taking medicine or other preparations which change blood color or the administration of intravascular dyes (such as methylene blue or indocyanine green, etc.) can drastically falsify the measurement results.

Other:

More conditions that may degrade pulse oximeter performance or affect the accuracy of the measurement include:

- Incorrect applications of the sensor
- Externally applied coloring agents such as nail polish or artificial nails,
- Placement of the sensor on an extremity with blood flow restrictors (arterial catheters, blood pressure cuffs, infusing lines, etc.),
- Low perfusion, venous pulsations, anemia or low hemoglobin concentrations
- Cardiac dysrhythmia like extrasystole or atrial / ventricular fibrillation
- Electromagnetic interference and electrosurgical interference

3 Guidelines for integration

3.1 SMARTsat® OEM I

3.1.1 Physical dimensions

The SMARTsat® OEM Boards are multi-layer PCBs with surface mount (SMT) components.

The SMARTsat® OEM I board dimensions are presented in the figures below. The drawings show the modules footprint and connectors location. It is recommended that the OEM customer uses an actual SMARTsat® module during the mechanical design process. 3-D files for the modules are available on request (STP).

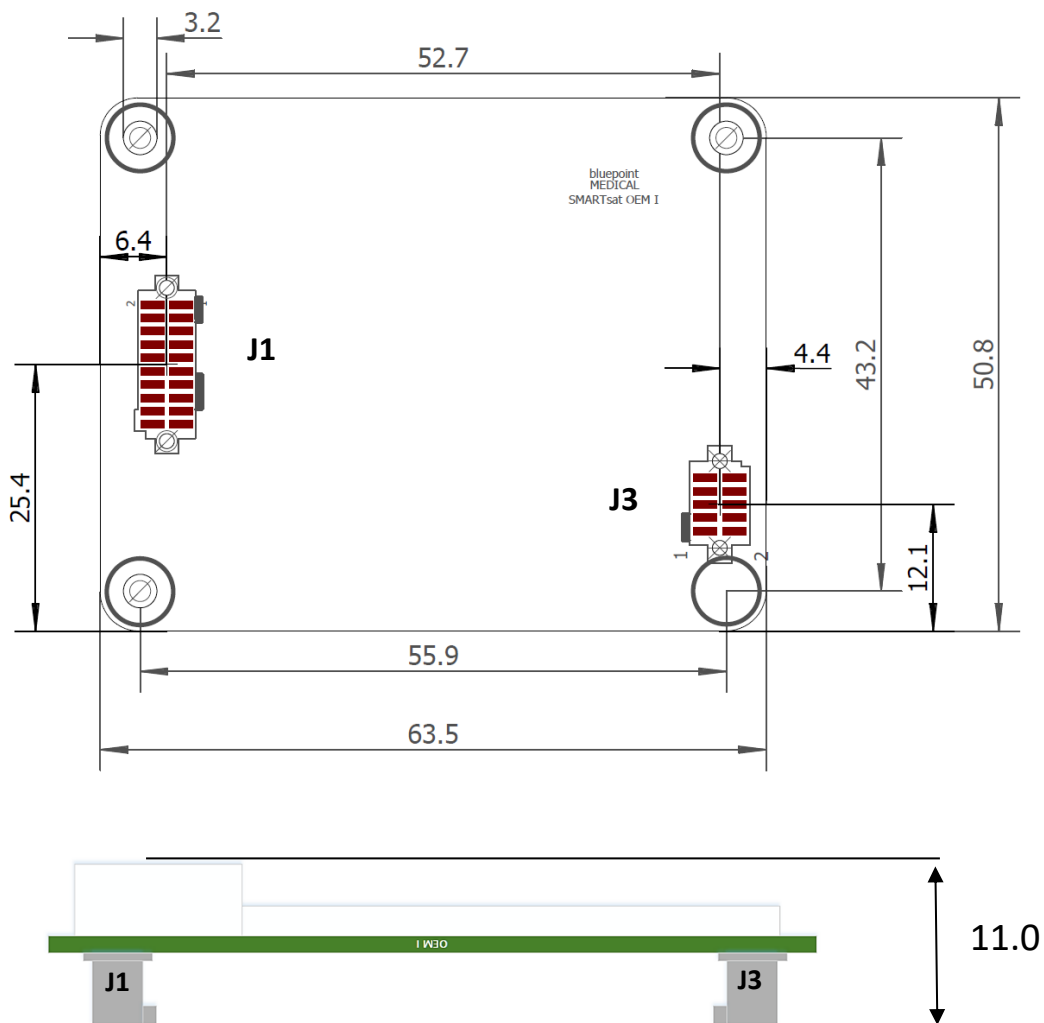


Fig. 3-1: SMARTsat® OEM I Board Physical Dimensions (in mm)

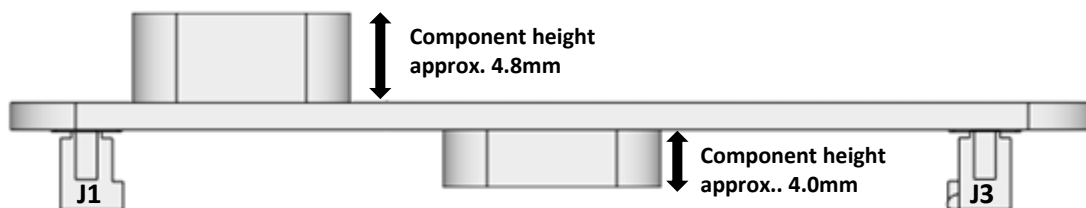
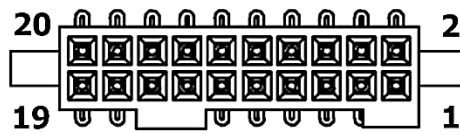


Fig. 3-2: SMARTsat® OEM I component height information (this information can be especially useful for host PCB layout)

3.1.2 Electrical interface

Sensor Connector J1:

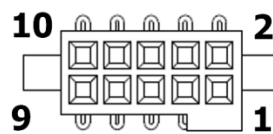


Part number: **Samtec SFML-110-T2-S-D-A**

PIN	Signal Description	PIN	Signal Description
1.	Detector Anode	11.	Reserved (Open)
2.	Detector Cathode	12.	Sensor ID
3.	Ground	13.	Reserved (Open)
4.	Ground	14.	Do not contact!
5.	Reserved (Open)	15.	RED LED
6.	Reserved (Open)	16.	Reserved (Open)
7.	Reserved (Open)	17.	Reserved (Open)
8.	Reserved (Open)	18.	Reserved (Open)
9.	Reserved (Open)	19.	IR LED
10.	Reserved (Open)	20.	Reserved (Open)

The mating parts for J1 on the host PCB is **Samtec TFML-110-02-L-D**

Power and Communication Connector J3:



Part number: **Samtec SFM-105-02-S-D-A**

PIN	Signal Description	PIN	Signal Description
1.	Input Power	6.	Ground
2.	Ground	7.	Reset
3.	Reserved (Open)	8.	Reserved (Open)
4.	Ground	9.	RxD (Receive data input)
5.	Reserved (Open)	10.	TxD (Transmit data output)

The mating parts for J3 on the host PCB is **Samtec TFM-105-02-L-D-A**

3.2 SMARTsat® OEM II and III

3.2.1 Physical dimensions

The SMARTsat® OEM Boards are multi-layer PCBs with surface mount (SMT) components. The SMARTsat® OEM II and OEM III board dimensions are presented in the figures below. The drawings show the modules footprint and connectors location. It is recommended that the OEM customer uses an actual SMARTsat® module during the mechanical design process. 3-D files for the modules are available on request (STP).

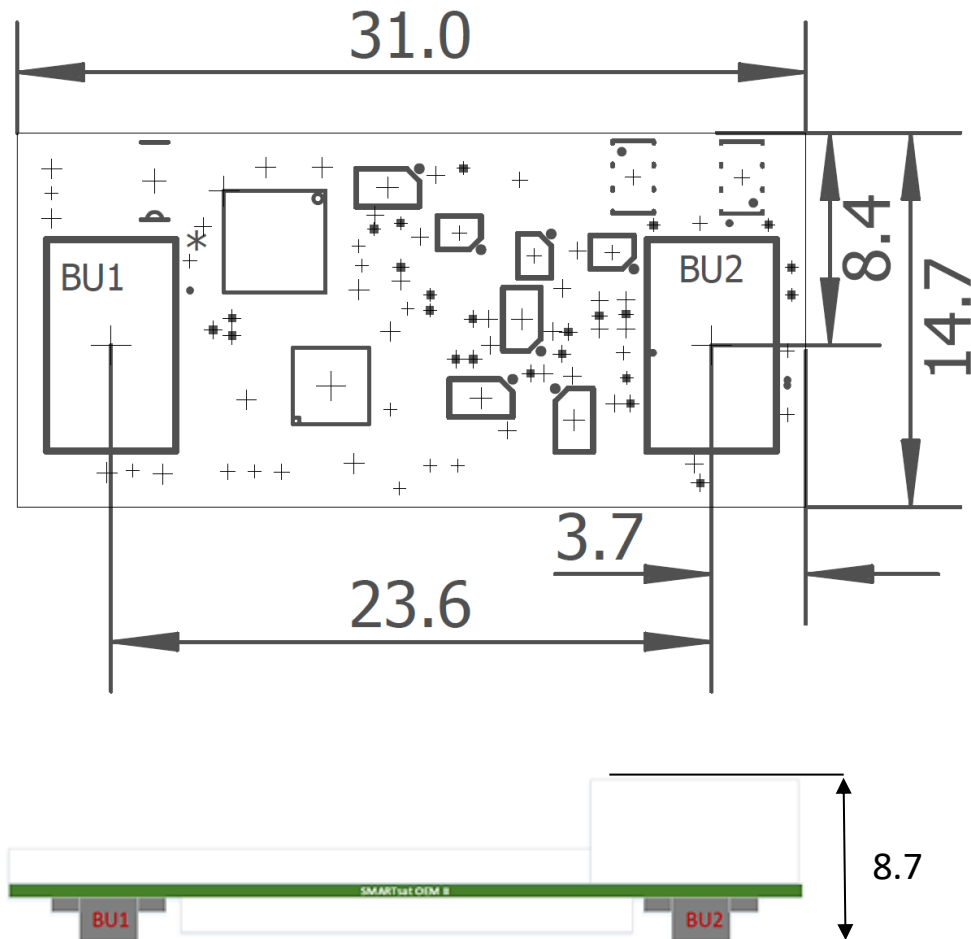


Fig. 3-3: SMARTsat® OEM II Board Physical Dimensions (in mm)

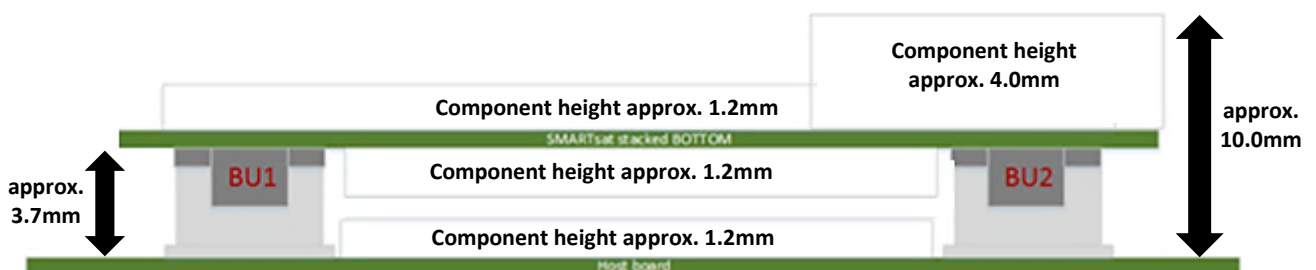


Fig. 3-4: SMARTsat® OEM II component height information (this information can be especially useful for host PCB layout)

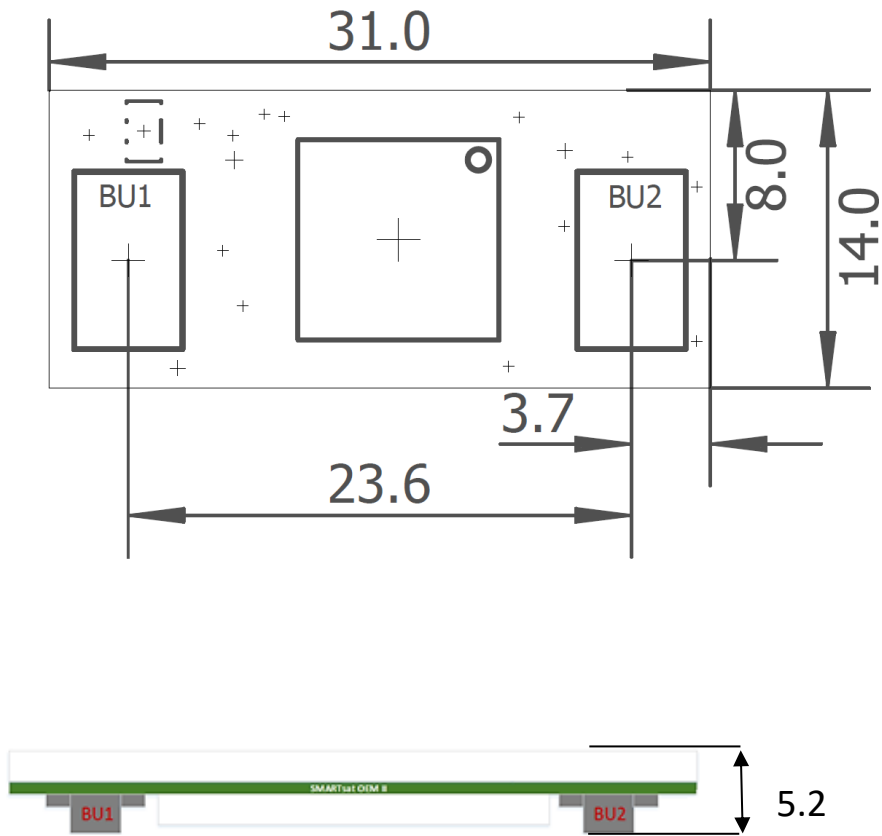


Fig. 3-5: SMARTsat® OEM III Board Physical Dimensions (in mm)

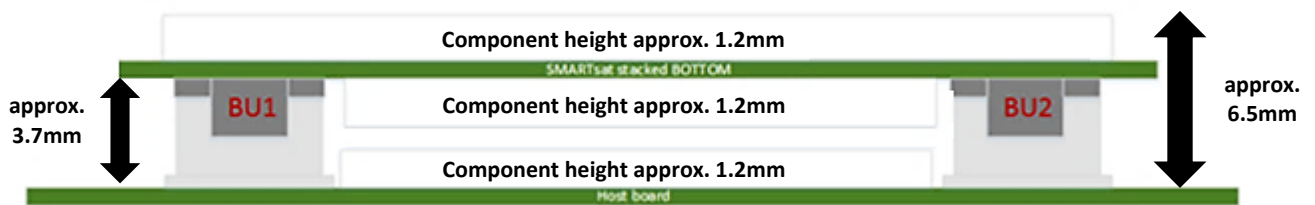
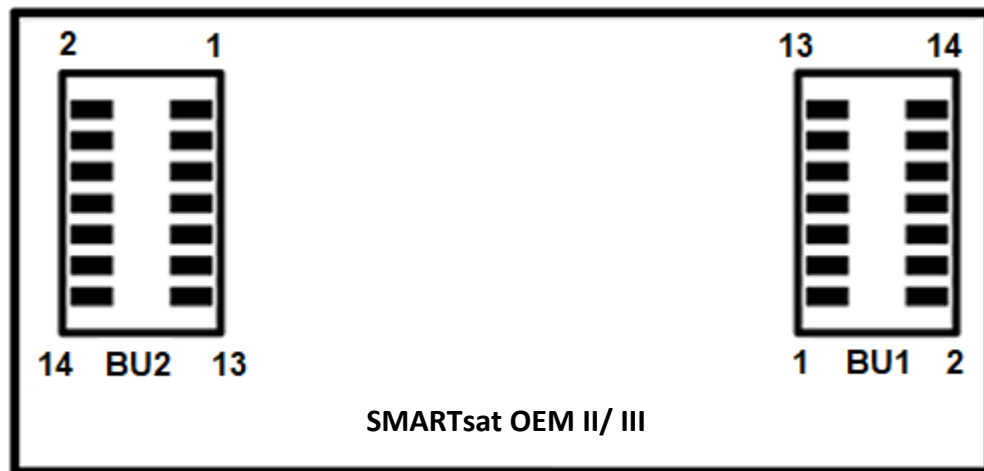


Fig. 3-6: SMARTsat® OEM III component height information (this information can be especially useful for host PCB layout)

3.2.2 Electrical interface

The OEM II and OEM III module are pin to pin compatible and can be replaced with each other, provided the host system considered the minimal larger outer dimensions of OEM II compared to OEM III

Power and Communication Connector BU1 and Sensor connector BU2 (Bottom View):



BU1/ BU2 Part number: **Samtec CLM-107-02-L-D**

Host Interface Connector Pin Assignments (BU1 and BU2)

PIN	BU1 Signal Description	PIN	BU2 Signal Description
1.	VCC Power input	1.	Not connected
2.	Ground	2.	Shield
3.	Reset	3.	Sensor ID
4.	TxD (Transmit data output)	4.	Detector Anode
5.	RxD (Receive data input)	5.	Detector Cathode
6.	Not connected	6.	IR LED
7.	Not connected	7.	Red LED
8.	Not connected	8.	Not connected
9.	Do not contact!	9.	Not connected
10.	Do not contact!	10.	Not connected
11.	Do not contact!	11.	Not connected
12.	Do not contact!	12.	Not connected
13.	Not connected	13.	Not connected
14.	Do not contact!	14.	Not connected

The mating part for BU1/ BU2 on the host PCB is **Samtec FTM-107-03-L-DV**.

3.3 External SMARTsat® EB

3.3.1 Physical dimensions

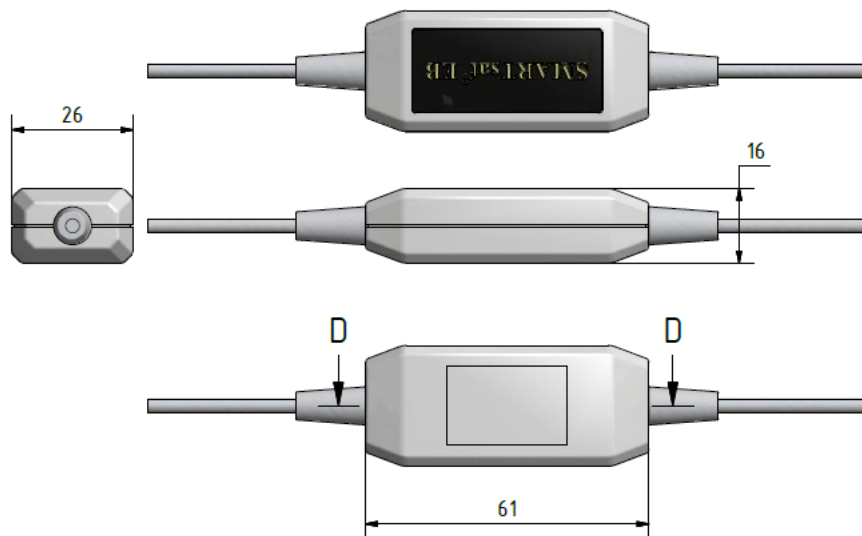


Fig. 3-7: SMARTsat® EB physical dimensions in mm

The cable length from the module to the host connector is 30cm and the overall length from host connector to sensor connector is 175cm.

3.3.2 Electrical interface

On one cable end the SpO2 sensor plug – 6 pin minimed (3.4.1) is available for the sensor connection. The SMARTsat® EB 4 PIN male host connector is on the other cable end which fits the SMARTsat® EB 4 PIN female host plug (REF: 205012004). Customized connectors are available on request.

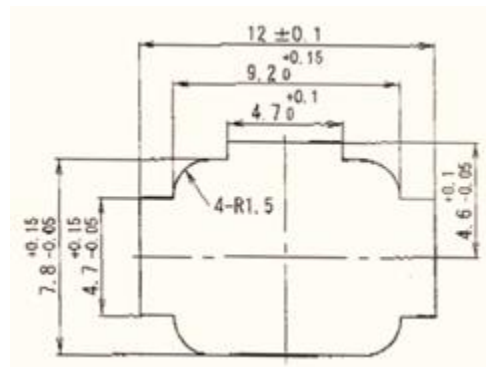
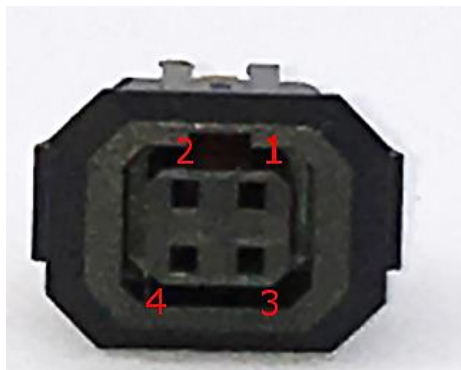


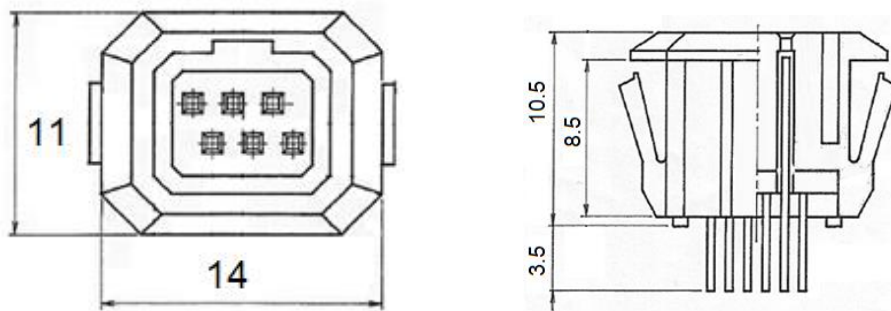
Fig. 3-8: SMARTsat® EB 4 PIN female host plug front view (left), dimensions mounting hole (right)

The SMARTsat® EB comes optional with an **USB** or **UART** interface.

PIN	Signal Description
1.	D+ (USB) / RX (UART)
2.	D- (USB) / TX (UART)
3.	Ground
4.	VCC (+5V)

3.4 SpO₂ sensor connection options

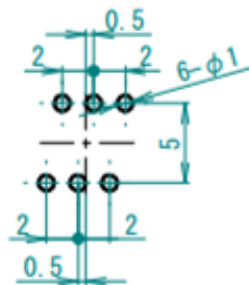
3.4.1 SpO₂ sensor plug – 6 pin minimed



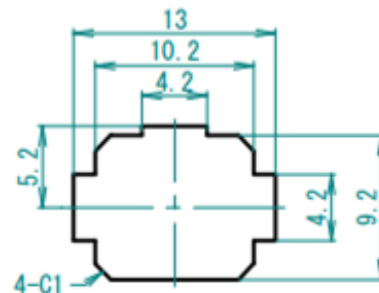
The connector is available as wire mount or pcb mount version:

Version	Wire mount - gold plated	PCB mount - silver plated
Order number (REF)	5020660002	10020660002
Image		

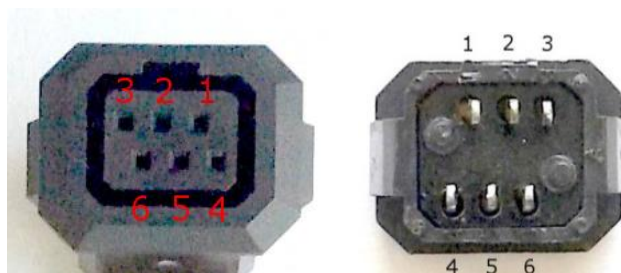
Mounting holes on PCB (thickness 1.6mm):



Mounting holes on Panel (thickness 1mm):



SpO₂ sensor plug – 6 pin female - Pin Assignments



PIN	Signal Description
1.	SENSOR ID
2.	LED RED ANODE
3.	LED IR ANODE
4.	Ground/Shield
5.	Detector Anode
6.	Detector Cathode

3.4.2 SMARTsat® SpO₂ sensor basic flex

The SMARTsat® SpO₂ sensor *basic flex cable* connects to a PCB flex connector

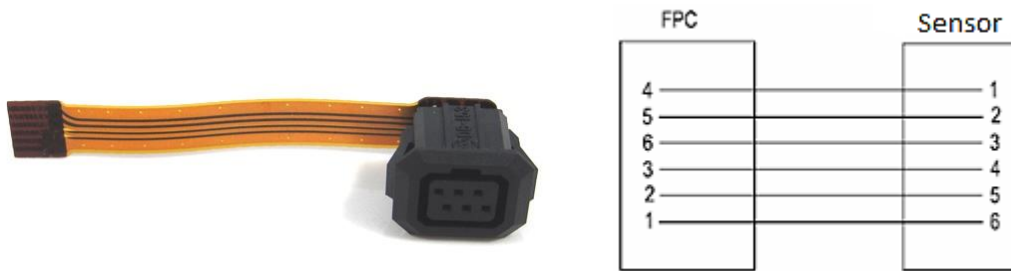


Fig. 3-9: SMARTsat® sensor basic flex cable with pin connector drawing (REF: 9020522001)

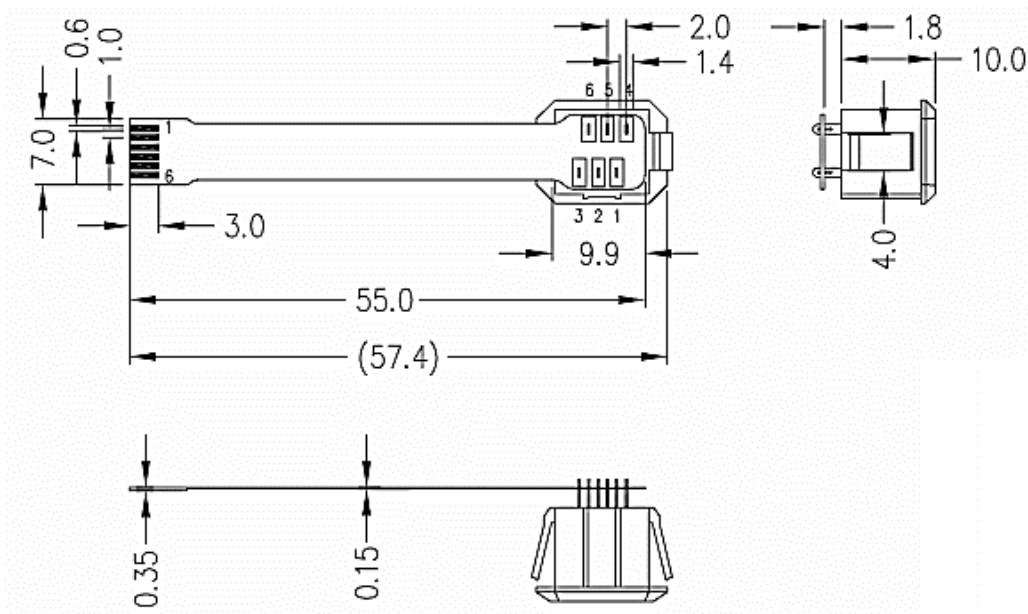


Fig. 3-10: SMARTsat® sensor basic flex cable dimensions

The mating connector for the flex cable is a 6 pin 1.0mm pitch FPC (e.g. **JST part # 06FMN-BMTTN-A-TF(LF)(SN)**).

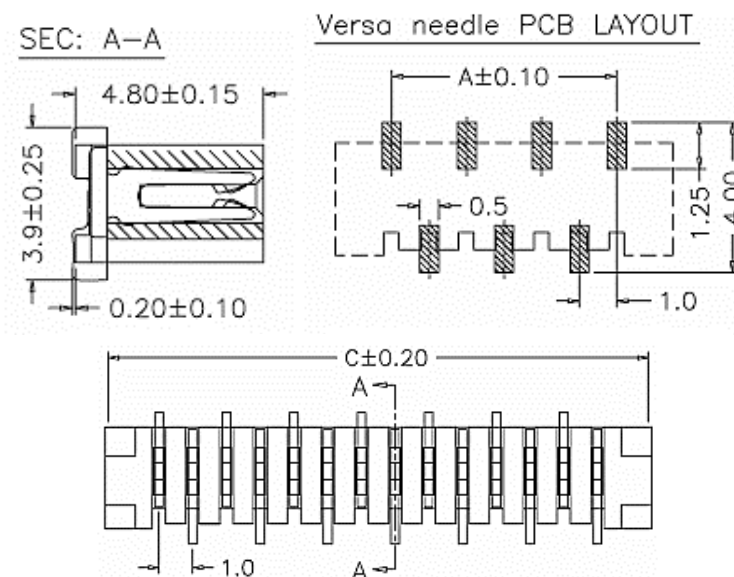


Fig. 3-11: PCB flex connector FPC1.0mm dimensions

3.4.3 SMARTsat® SpO₂ sensor low noise flex

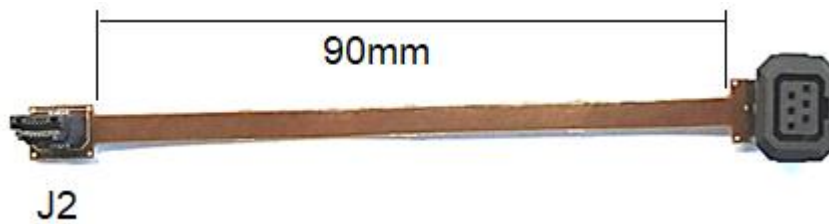
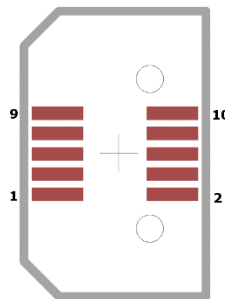


Fig. 3-12: SMARTsat® SpO₂ sensor low noise flex (REF: 8110140014)

The 4 layer flexible connection has a length of 90 mm. The shielded flex is ideal for use with the SMARTsat® OEM I/ II to support the low perfusion performance of the module.

The mating connector for the host pcb is a 10 pin dual row connector with a pitch of 0.635 mm (**Samtec part # LSS-105-01-L-DV-A**).



Mating Host PCB connector J2

J2 Host PCB connector for SpO₂ sensor low noise flex - Pin Assignments

PIN	Signal Description
1.	Ground/Shield
2.	Ground/Shield
3.	Detector Anode
4.	Detector Cathode
5.	Ground/Shield
6.	Ground/Shield
7.	Not connected
8.	Sensor ID
9.	LED RED ANODE
10.	LED IR ANODE

3.4.4 SMARTsat® SpO₂ sensor low noise flex – OEM I

Directly connect the SpO₂ sensor to the SMARTsat® OEM I module at **J1** (see 3.1.2) with the SMARTsat® SpO₂ low noise flex - OEM I.



Fig. 3-13: SMARTsat® SpO₂ low noise flex - OEM I (REF: 12110140001)

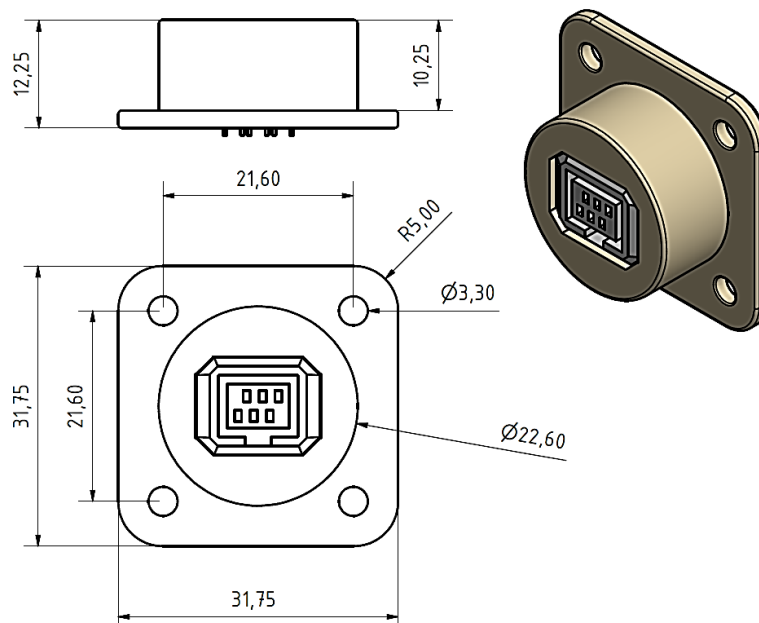


Fig. 3-14: SMARTsat® SpO₂ low noise flex - OEM I - connector - dimensions in mm

4 HOST system considerations

4.1 Power supply requirements

It is the responsibility of the host system to guarantee that power supplied to the SMARTsat® module is within specification. A linear regulator is recommending for stabilizing the power supply (e.g. Texas Instruments REG113-3.3). SMARTsat® is monitoring the power supply and in case, that the voltage is outside the limits an error message will be send that indicates a potentially incorrect measurement.

The baud rate and sampling rate has significant influence on the total power consumption of the SMARTsat® OEM modules.

The influence of sampling rate and baud rate on the total power consumption is summarized in the tables and plots below.

4.1.1 Power consumption and sampling rate

Table 6: Maximum power consumption depending on sampling rate (@baud 230400)

SMARTsat® Module	Supply voltage [V]	I [mA] @75Hz	I [mA] @300Hz
OEM III	3.3	12	32
OEM II	3.3	29	47
OEM I	5	28	46
EB with OEM III	5	12	32
EB with OEM II	5	28	46

4.1.2 Power consumption and baud rate

The following table shows the dependence between baud rate and maximum power consumption

Table 7: Dependence between baud rate and max. power consumption

Baud rate	SMARTsat® OEM I (Power supply 5V)		SMARTsat® OEM II (Power supply 3.3V)		SMARTsat® OEM III (Power supply 3.3V)	
	I[mA] @75Hz	I[mA] @300Hz	I[mA] @75Hz	I[mA] @300Hz	I[mA] @75Hz	I[mA] @300Hz
9600	29.5	47	29.6	47.1	13.6	32.1
19200	28.7	46.7	28.9	46.9	12.7	31.8
38400	28.5	46.6	28.7	46.7	12.4	31.7
57600	28.3	46.5	28.5	46.7	12.2	31.6
115200	28.2	46.4	28.5	46.6	12	31.6
230400	28.2	46.4	28.5	46.6	12	31.6

4.2 Power-ON initialization and self-test

After power on the SMARTsat®, board performs a self-test. The initialization time is approximately 1.5 sec. The self-test verifies the integrity of the hardware components like ROM, RAM, and CPU. SMARTsat® begins operation, if no error was detected during the self-test routine. If an error is detected, a status and/or error message will be send to the host system and the normal operation will be stopped.

4.3 Reset

The reset pin is low active and an open drain output. For normal operation, the reset pin should be at high level. You can leave the pin unconnected, all SMARTsat® OEM boards are equipped with a pull up resistor. After reset a Power-ON initialization and self-test (section 4.2) will be performed.

NOTE: For safety reasons the host is recommended to perform a reset, if measurement data is not continuously receive latest 2 seconds after module power on and during operation. Switch off the supply of the module if after the reset still no measurement data is received. Send the defective module to bluepoint MEDICAL.

4.4 Shielding/ Crosstalk

The currents in the two detector lines anode and cathode are in the nA range. Due to this fact the electric wiring requires adequate handling.

Disturbances due to inductive coupling on these lines have a direct effect on the measurement quality. Following points should be considered:

- should be kept as short as possible
- should be wired exactly parallel a short distance from each other
- should be kept away from electromagnetic noise sources
- should be surrounded by a ground plane

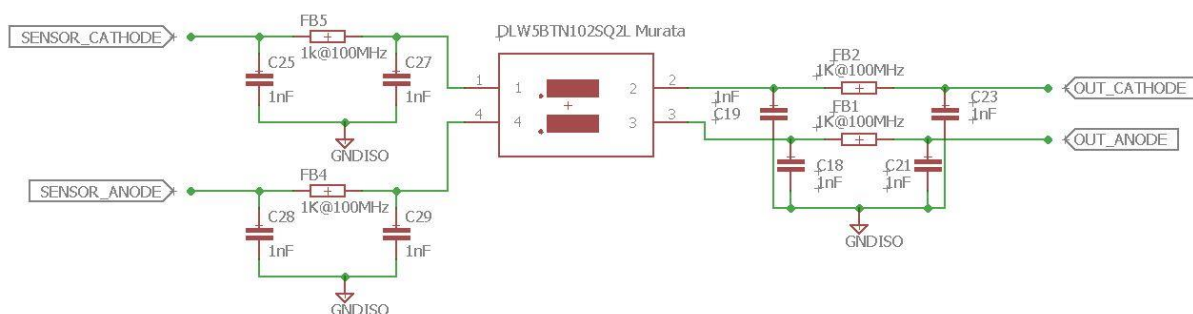
4.5 Electrostatic discharge (ESD) protection

ESD protection for the SMARTsat® boards must be provided by the host system. The SMARTsat® boards contain static sensitive devices and therefore should itself be treated as a static sensitive device.

4.6 Electromagnetic compatibility

For certification of medical devices a verification of the host system with integrated SMARTsat® including connected sensor according to IEC 60601-1-2 is mandatory.

Following figure shows an example for a passive network which can be used in a host system to reduce the influence of radiated immunity. It is recommended that such a network is used for the LED and Detector lines.



The networks consist of three sections:

1. Discrete PI-Filter with a ferrite bead and an impedance of 1 kOhm at 100 MHz
2. Common mode choke “Murata - DLW5BTN102SQ2L”
3. Discrete PI-Filter with a ferrite bead and an impedance of 1 kOhm at 100 MHz

The SMARTsat® OEM I is already equipped with an EMI suppressor network. Depending on the host system additional measure may be necessary.

4.7 Patient isolation requirements

There is no patient isolation on the SMARTsat® boards. The host system must provide electrical isolation for all connections to the module to meet the requirements of EN 60601-1 medical electrical equipment safety requirements and other electrical safety specifications as applicable. The sensor isolation may not be considered when evaluating patient isolation.

4.8 Product standards

SMARTsat® has been developed to meet the requirements of the standards listed below.

Applied Standards	
SMARTsat® module	IEC 60601-1, Ed. 3.1 (excluding parts related to the host monitor) IEC 60601-1-2, 4th Ed (to be tested with intended host monitor) EN ISO 80601-2-61:2019 (excluding parts related to the host monitor)
SMARTsat® sensors	EN ISO 10993-1:2020; ISO 10993-5:2009; ISO 10993-10:2021; EN ISO 10993-23:2021

NOTE: All corresponding standards are to be taken into consideration during integration in a host system. Any influences on or from the host system are not considered.

5 Host Communication

5.1 Interface specification

The signals used for communication are the TX and RX signal lines. TX is an output line, used to transmit data to the Host. RX is an input line, used for receiving data from the Host.

Standard settings are: 115200 Bd, 8 data bits, no parity, 1 stop bit. No hard or software handshake is used.

The detailed communication protocol is described in the separate document “**SMARTsat® Communication Protocol**” [1].

5.2 Electrical properties RX/TX for

5.2.1 SMARTsat® OEM II and III

	V_{min}	V_{norm}	V_{max}
Logical 0	-0.3	0	0.99
Logical 1	2.31	3.3	3.6

NOTE: available also for SMARTsat® OEM I on request

5.2.2 SMARTsat® OEM I

	V_{min}	V_{norm}	V_{max}
Logical 0	-0.2	0	0.4
Logical 1	$0.67 \cdot VCC$	VCC	$VCC + 0.3$

NOTE: Max3378 Lvl Shifter

5.3 Baud rate configuration

The default shipping baud rate of SMARTsat® is 115200 Bd. The host can change the baud rate using the communication protocol [1]. 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.

NOTE: The baud rate can only be changed 1000 times in total.

6 Development kit

bluepoint MEDICAL offers a development kit for analyzing the SMARTsat® performance and communication protocol using the PC based SMARTsat® Protocol Viewer.

The development kit includes:

- SMARTsat® development board
- SMARTsat® OEM module
- USB cable
- SoftFlap® SpO₂ sensor SF7500
- CD with the SMARTsat® Protocol Viewer PC-Software, SMARTsat® Emulator PC-Software, Integration guide (this document), Communication Protocol Specification [1] and Host Validation Checklist [2].

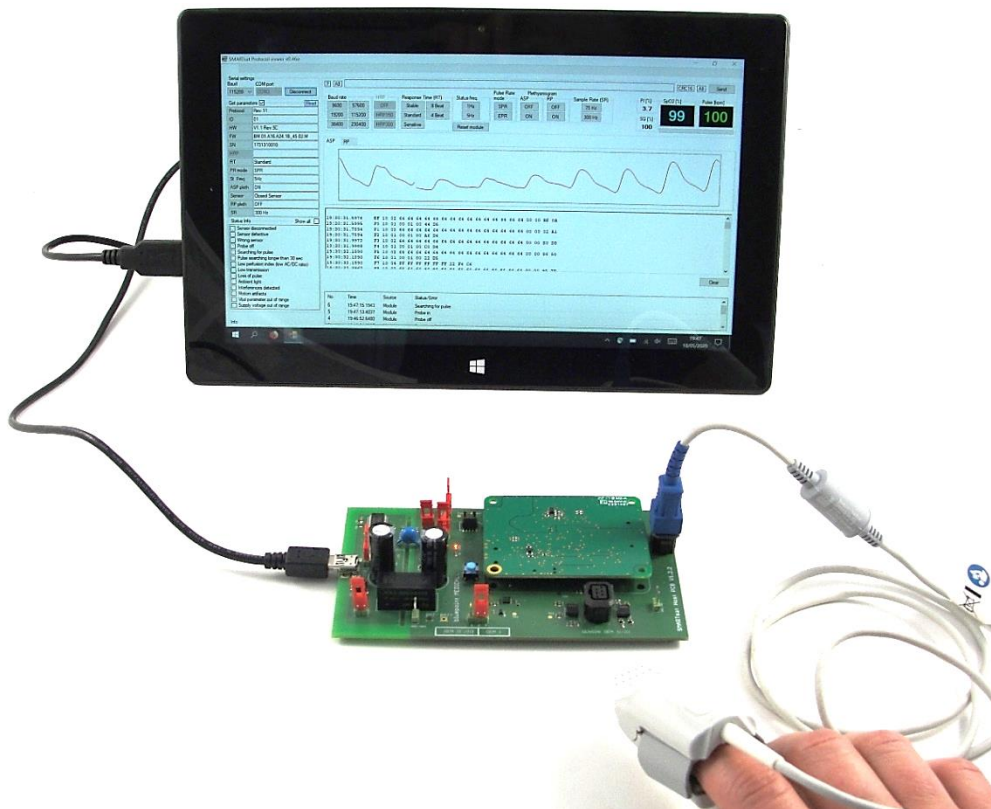


Fig. 6-1: SMARTsat® OEM I Development kit (tablet PC not part of delivery scope)

6.1 SMARTsat® development board

1) Connect the SMARTsat® module and SpO₂ sensor to the development board.

In addition some jumpers and a reset button are available for analyzing purposes (see figure below).

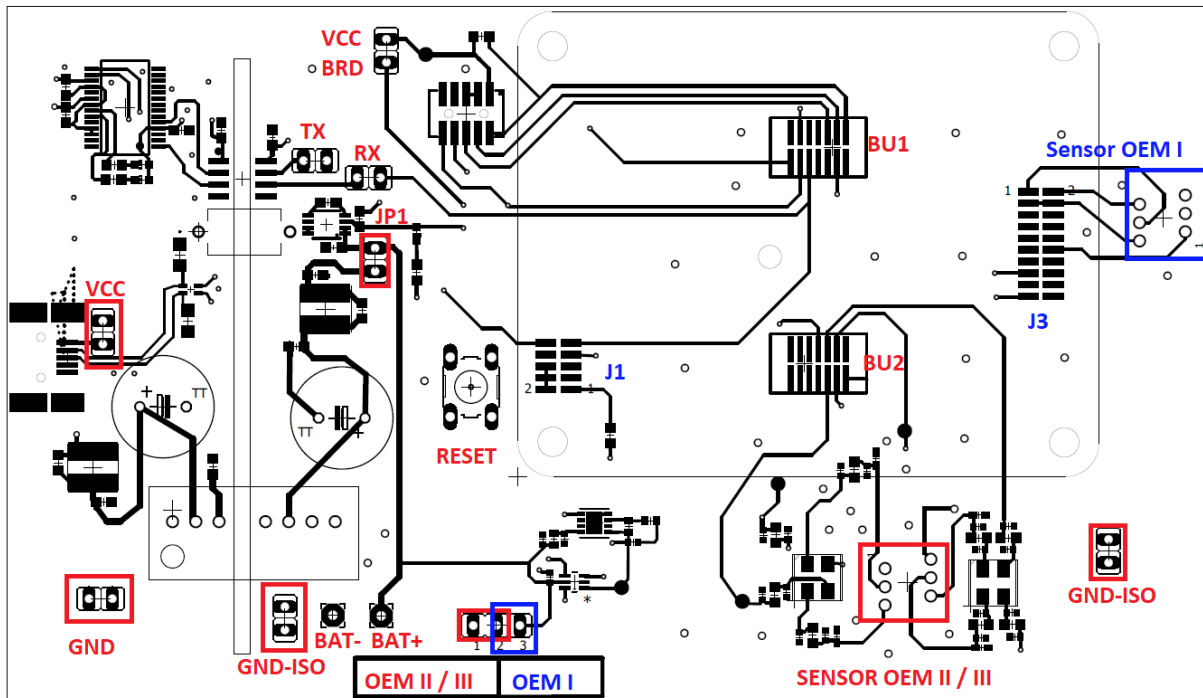


Fig. 6-2: Overview of SMARTsat® Host PCB V1.2.2

Function	Description
VCC	USB voltage 5 V (Jumper connected)
TX	Module UART TxD (Jumper connected)
RX	Module UART RxD (Jumper connected)
JP1	Isolated 5 V (Jumper connected)
VCC_BRD	Isolated LDO 3.3 V (Jumper connected)
OEM II / III	Use PCB with SMARTsat® OEM II/ III (Jumper)
OEM I	Use PCB with SMARTsat® OEM I (Jumper)
BU2 / BU1	OEM II/ III connectors
Sensor OEM II/ III	Connection to SpO ₂ sensor using <i>SMARTsat® sensor</i>
J1/ J3	OEM I connectors
Sensor OEM I	Connection to SpO ₂ sensor using <i>SMARTsat® sensor</i>
Reset	Perform hardware reset
BAT-/BAT+	Connection to use external power supply (JP1 must not be connected)

Ensure the jumpers have been connected according to the used SMARTsat® module type and that the SMARTsat® module is correctly connected (see images below).

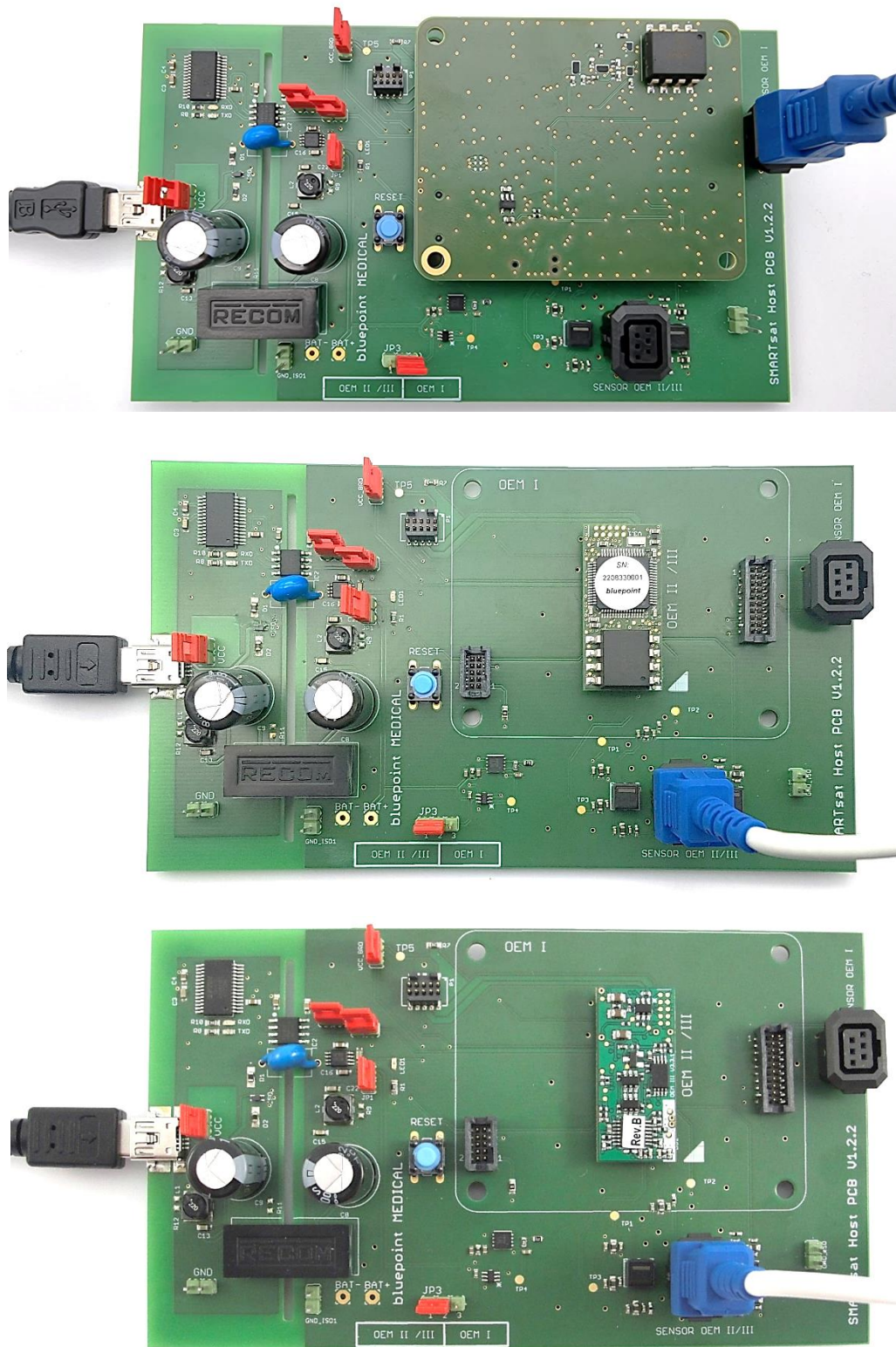


Fig. 6-3: Orientation of SMARTsat®, connection of jumpers and SpO₂ sensor on the development board v1.2.2

NOTE: The SMARTsat® development board is supplied via the USB connection to a PC. Depending on the PC and its configuration the supply can be very noisy. This can have significant influence on the signal quality as the power supply specifications (ripple <10 mV) are not met. Such distortion becomes clearly visible e.g. during charging of the laptop battery during data acquisition.

Supply the development board using a battery (OEM I: 4.9 V – 5.5 V; OEM II/III: 3.7 V – 5.5 V) to eliminate the USB voltage noise. This is done by removing the JP1 and connecting the battery to BAT-/BAT+ connector.

2) Connect the development board via USB to a PC and install the USB drivers (provided on CD)



The SMARTsat® development board is using an FTDI UART bridge. After connecting the board with the Desktop PC the UART latency of the virtual COM port has to be set to 4 msec to avoid loss of data and ensure good runtime performance (see figure below).

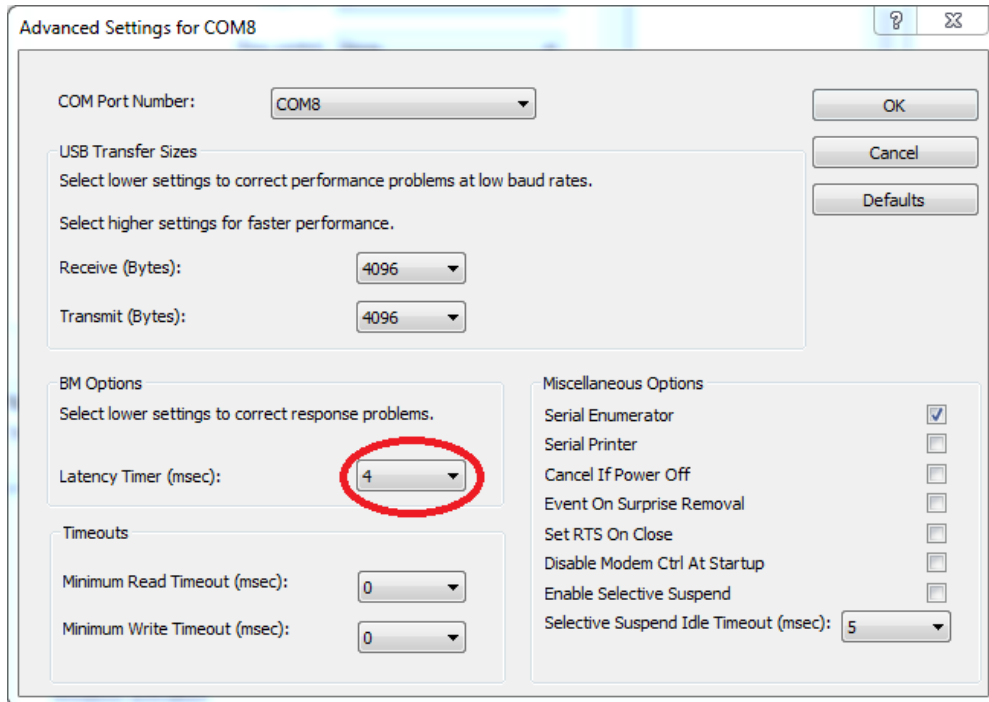


Fig. 6-4: Virtual COM port UART settings

6.2 SMARTsat® Protocol Viewer and Emulator

1. Serial settings: Baud (115200), COM port (COM4), Disconnect.

2. Get parameters: Protocol (Rev.11), ID (07), HW (V2.3.1 Rev.D), FW (BM.07.A16.A24.1B_45.02.M), SN (1840330018), HRP, RT (Standard), PR mode (SPR), St. Freq (5Hz), ASP pleth (OFF), Sensor (Closed Sensor), RP pleth (ON), SR (300 Hz).

3. Status Info: ☐ Sensor disconnected, ☐ Sensor defective, ☐ Wrong sensor, ☐ Probe off, ☐ Searching for pulse, ☐ Pulse searching longer than 30 sec, ☐ Low perfusion index (low AC/DC ratio), ☐ Low transmission, ☐ Loss of pulse, ☐ Ambient light, ☐ Interferences detected, ☐ Motion artifacts, ☐ Vital parameter out of range.

4. Data display: Baud rate (9600, 57600, 19200, 115200, 38400, 230400), HRP (OFF, HRP150, HRP300), Response Time (RT) (Stable, Standard, Sensitive), Status freq. (1Hz, 5Hz), Pulse Rate mode (SPR, EPR), Plethysmogram (ASP: OFF, ON; RP: OFF, ON), Sample Rate (SR) (75 Hz, 300 Hz), PI [%] (1.5), SpO2 [%] (99), Pulse [bpm] (75).

5. Waveform plot: ASP, RP.

6. Hex data log:

No.	Time	Source	Status/Error
14	18:33:39.6976	Host	Frame counter error detected
13	18:33:39.6976	Host	Frame counter error detected
12	18:33:39.6855	Host	Frame counter error detected

7. Hex data log:

No.	Time	Source	Status/Error
18:34:19.8352	AE 10 03 89 4B 02 C9 BE		
18:34:19.8432	AF 10 03 CB 4B 02 0C 1F		
18:34:19.8472	B0 10 03 11 4C 02 A8 3E		
18:34:19.8552	B1 10 03 6D 4C 02 A1 FE		
18:34:19.8631	B2 10 03 D2 4C 02 76 CF		
18:34:19.8671	B3 10 03 36 4D 02 00 8F		
18:34:19.8752	B4 10 03 AD 4D 02 58 FF		
18:34:19.8831	B5 10 03 16 4E 02 5C 8E		
18:34:19.8871	B6 10 03 51 4E 02 7A 3E		
18:34:19.8952	B7 10 03 E1 4C 02 2C 3F		

8. Hex data log:

No.	Time	Source	Status/Error
14	18:33:39.6976	Host	Frame counter error detected
13	18:33:39.6976	Host	Frame counter error detected
12	18:33:39.6855	Host	Frame counter error detected

9. Hex data log:

No.	Time	Source	Status/Error
14	18:33:39.6976	Host	Frame counter error detected
13	18:33:39.6976	Host	Frame counter error detected
12	18:33:39.6855	Host	Frame counter error detected

10. Hex data log:

No.	Time	Source	Status/Error
14	18:33:39.6976	Host	Frame counter error detected
13	18:33:39.6976	Host	Frame counter error detected
12	18:33:39.6855	Host	Frame counter error detected

Fig. 6-5: SMARTsat® ProtocolViewer

To view and store data sent by the SMARTsat® module open the SMARTsat® Protocol Viewer (SMARTsat®ProtocViewer.exe provided on CD).

Functions available are described in the table below and in Figure 6-5.

Nr.	Description
1.	Select Baud and COM port and start the communication using the CONNECT button
2.	Continuous display of transmitted SMARTsat® status information
3.	Continuous display of transmitted measurement values SpO ₂ and pulse rate, perfusion index (PI) and signal quality (SQ).
4.	Display of IR transmission plethysmogram. If the High Resolution Plethysmogram is activated, the display switches to the RP (Raw Pleth) tab and displays the absorption plethysmogram.
5.	Selected commands can be send to the SMARTsat® module by using the buttons e.g. Set response time, activate RP etc.
6.	Possibility to send commands to SMARTsat® according to the SMARTsat® Communication Protocol [1]. Send the command (e.g. enter 10 31 73 to set baud 115200) to the module by pressing the SEND button or ENTER NOTE: The PC-SW automatically links the Identifier with the attribute 0x80 OR , adds the Start flag (0xA8), End flag (0xA8) and the correct CRC before sending the command to the SMARTsat®.
7.	Transmitted SMARTsat® data in HEX format. Start flag (0xA8) and End flag (0xA8) have been removed. Data has been destuffed. Data can be exported using the right mouse context menu.
8.	List of status and errors send by SMARTsat® including frame errors which occurred during communication between SMARTsat® and the Protocol Viewer application. The log entries can be exported using the right mouse context menu.
9.	Current module settings. These are first updated upon pressing the <i>connect</i> button. Thereafter they are updated if the setting is changed, or if the <i>Get parameter quick button</i> is pressed.
10	Start store of RP data (or HRP for Protocol rev.8 and smaller) and results by activating the SAVE check box and entering a file name. Stop data acquisition by deactivating the check box. The file is also closed if the application is closed or if the port is disconnected (1.). The RP data is stored in the .txt including the start time and module settings. Each second the SpO ₂ , pulse rate (PR), perfusion index (PI) and signal quality (SQ) is plotted next to the RP, separated by a semicolon (e.g. 4508517;99;73;7.0;100 // HRP; SpO ₂ ; PR; PI; SQ)

6.3 SMARTsat® Protocol Emulator

Verify the host system using the SMARTsat® Emulator provided on the CD. This tool sends data in the SMARTsat® protocol format (see Figure below).

Use the development kit (or a level shifter like FTDI_TTL-232R) to connect the host system (Rx, Tx, GND) via USB to the PC. The SMARTsat® is simulated by the Emulator. Status and measurement results sent can be changed and errors generated by the emulator to verify the host system behavior.

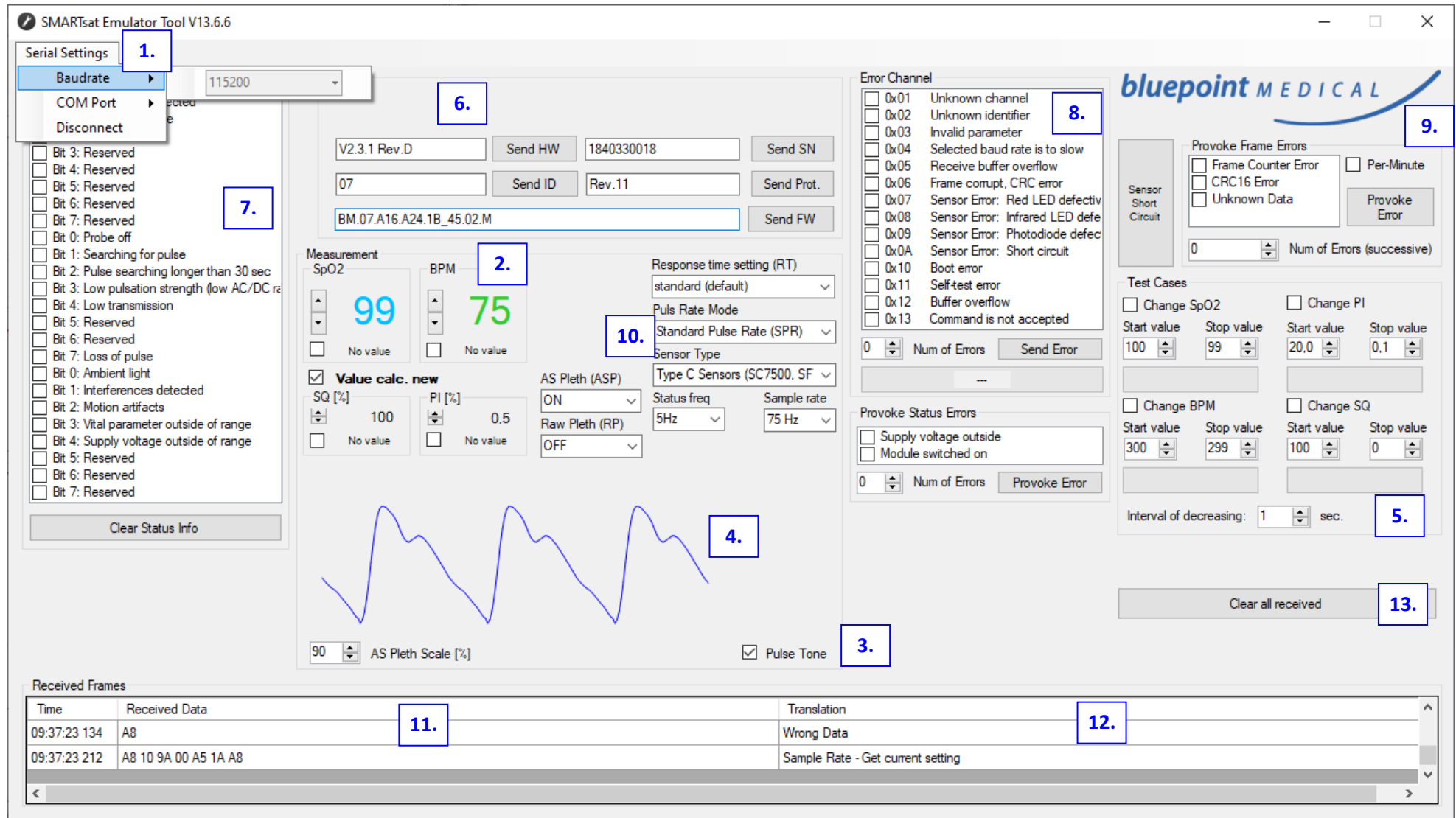


Fig. 6-6: SMARTsat® Emulator

Nr.	Description
1.	Select COM port and baud rate to open the serial connection using the Serial Settings button.
2.	Current measurement values transmitted to the host
3.	Adjustment of the measurement values. The <i>Pulse Tone</i> checkbox enables/disables the pulse beep indicator
4.	Normalized Plethysmogram transmitted to the host. The same waveform is used for the AS (auto scaled) and RP (raw) plethysmogram.
5.	Generation of test cases. Enter a start and stop value for a measurement value and start the test case using the <i>change ...</i> Checkbox. The value is changed automatically. The change interval can be set at box <i>Interval of decreasing</i> .
6.	Hardware and firmware information of the simulated SMARTsat® module. This information can be requested by the host or is sent by the emulator using the buttons next to the entered strings.
7.	By activating the checkboxes the appropriate flags in the status information frame are set and sent continuously to the host.
8.	Generation of error channel messages. Activate a checkbox and enter the number of errors transmitted to the host. The errors are sent using the Send Error button.
9.	Generation communication errors. Activate a checkbox and enter the number of errors transmitted to the host. The errors are sent using the Provoke Error button.
10	Settings configuration of the simulated SMARTsat® module and sensor type. Use the drop down menus to change the settings.
11	All data received from the host. The information is not filtered or post-processed. The valid data frames are already de-stuffed.
12	Description of the valid data frames received from the host.
13	Use this buttons to clear the received data.

6.4 Communication Protocol Verification Procedure

To prevent communication errors a proper validation of the communication protocol in the host system is mandatory before delivery of serial production SMARTsat® modules to the host.

The SMARTsat® I-III Host Validation Checklist is available in a separate document [2]. Depending on the intended use of the host system not every part of the protocol must be implemented. The host validation is passed, if all the mandatory sections in the checklist are implemented and none of the implemented sections failed.

Based on the Risk Analysis of the host system, the implemented actions may differ from the suggestion, provided the risk has been addressed appropriately.

7 Technical data

Functional measurement range:

Parameter	OEM I/II	OEM III
SpO ₂	0 – 100 %	
Pulse Rate	Standard Mode: 30 – 240 bpm; Enhanced Pulse Rate Mode (EPR): 20 – 300 bpm	
Perfusion Index	0.02 – 20 % (no motion)	0.1 – 20 % (no motion)

Accuracy:

Parameter	Measurement range	Accuracy
SpO ₂	0 – 100 %	70 – 100 %: $A_{rms} \leq 2\%$ (no motion, incl. low perfusion ³⁾ ^{1, 4}
		60 – 80% : $A_{rms} \leq 2\%$ (no motion, incl. low perfusion ³⁾ ^{1, 4}
		70 – 100 %: $A_{rms} \leq 3\%$ (motion condition) ²
		<60%: unspecified
Pulse Rate	Standard Mode: 30 – 240 bpm	$A_{rms} \leq 2\text{bpm}$ (no motion, incl. low perfusion ³⁾ ⁵ $A_{rms} \leq 3\text{bpm}$ (motion condition ²⁾
	Enhanced Pulse Rate Mode (EPR): 20 – 300 bpm	

1) Because pulse oximeter measurements are statistically distributed, only about two-thirds of measurements can be expected to fall within $\pm A_{rms}$ of the measured values by a co-oximeter.

2) Tested with all Fluke Index II Oximeter tester motion patterns with pattern specific motion frequency of 0,5Hz to 6Hz at perfusion PI: 0.65% to 5% including non-repetitive motion and motion repeating every 0.5Hz.

3) Tested with Fluke ProSim 8 Oximeter tester at infrared percentage modulation PI: 0.7% to 0.1%

4) Applies to reusable SMARTsat® sensors, refer to sensor instructions for use for sensor specific accuracy claims

5) Tested with Fluke ProSim 8 Oximeter tester throughout the pulse rate range of 20 – 300bpm

Response time:

Parameter	Specification
Display of first value	The time until the first value is displayed after application is depending on the measurement conditions (perfusion, motion artefacts) and is in the following range: SpO ₂ : 3 to 7 s; Pulse Rate: 5 to 8 s.
Response time modes	Refer to section 2.2.2
Data update period	Typically, the displayed data update period is 1s. The data update is delayed in case no new valid data is available, e.g. due to excessive signal distortion. The longest data update period is 28 s.

Power requirements:

	OEM I	OEM II	OEM III	EB (OEM II)	EB (OEM III)
Input voltage range [VDC] (Ripple <10mV)	3.8 – 5.5	3.3 – 4.0	3.2 – 3.6	4.5 – 5.25	

Parameter	OEM I		OEM II		OEM III		EB (OEM II)		EB (OEM III)	
Supply voltage [VDC]	5		3.3		3.3		5		5	
Sample Rate [Hz]	75	300	75	300	75	300	75	300	75	300
Typical power consumption [mW]	96	187	65	125	33	77	64	124	53	132
Maximum power consumption [mW]	140 ¹⁾	230 ¹⁾	96 ¹⁾	155 ¹⁾	40	106	140 ¹⁾	230 ¹⁾	60	160

¹⁾ The maximum power consumption was determined under extreme ambient light conditions; the typical value is significantly lower.

NOTE: The baud rate and sampling rate has significant influence on the total power consumption of the SMARTsat® OEM modules. (see Chapter 4.1 for more detail). Here listed specifications are valid for baud rate 230400 Bd and raw plethysmogram (RP) switched no.

Environmental specifications:

Parameter	OEM I	OEM II	OEM III	EB
Operating temperature	-20°C to 60°C			
Storage temperature	-40 °C to +70 °C			
Relative humidity	15 % to 95 % (operation, non-condensing) 10 % to 95 % (storage, non-condensing)			
Altitude ¹⁾	620 ¹⁾ to 1060 hPa (620 hPa corresponding to an altitude of 4000m)			

¹⁾ May differ depending on host specification and validation tests

Serial communication and data:

Parameter	OEM I/II/ III
Time until the first command is accepted after switch-on	1.5 sec
Baud Rate	9600 Bd up to 230400 Bd (min. rate for Raw Plethysmogram: 115200 Bd)
Sampling rate adjustable to	75 Hz, 300 Hz

Dimension:

Parameter	OEM I	OEM II	OEM III
Dimensions (L x W x H)	63.5mm x 50.8mm x 11.0mm	31.0mm x 14.7mm x 8.7mm	31.0mm x 14.0mm x 5.2mm

Classification:

Requirement	Classification
According to the degree of protection against harmful ingress of water according to EN 60601-1	Applicable to SpO2 sensors. Refer to respective sensors instructions for use.
Sterility according to EN 60601-1	The SMARTsat® module, sensors and cable are not sterile
Mode of operation according to EN 60601-1	Continuous mode
the degree of protection against electric shock according to EN 60601-1	The SMARTsat® pulse oximeter sensors together with the SMARTsat® module are classified as TYPE BF applied part
Medical Electrical System (ME System)	The SMARTsat® module integrated in a host system shall be considered as a ME system
Classification according to MDR, Annex VIII	<p><u>Integrated SMARTsat® Module:</u></p> <p>IIa¹ (Rule 10 applies); IIb² (Rule 10 applies)</p> <p>¹ If integrated into a medical device monitor which allow direct diagnosis or monitoring of vital physiological processes (e.g. Spot check of SpO₂ and pulse rate without alarm function.</p> <p>² If integrated into a medical device monitor specifically intended for monitoring of SpO₂ and pulse rate, where the nature of variations is such that it could result in immediate danger to the patient (e.g. alarm monitor or monitoring of neonates)</p> <p><u>SMARTsat® SpO2 sensors:</u></p> <p>IIb (Rule 10 applies)</p> <p><u>SMARTsat® SpO2 cables:</u></p> <p>I (Rule 1 applies)</p>

8 Order numbers

8.1 Development kits, modules and connectors

Product	REF
SMARTsat® I development kit SMARTsat® OEM I module; Development platform (incl. USB cable and PC software); SoftFlap SpO ₂ sensor SF7500	8110140009
SMARTsat® II development kit SMARTsat® OEM II module; Development platform (incl. USB cable and PC software); SoftFlap SpO ₂ sensor SF7500	8110140010
SMARTsat® III development kit SMARTsat® OEM III module; Development platform (incl. USB cable and PC software); SoftFlap SpO ₂ sensor SF7500	8110140012
SMARTsat® OEM I module	8110502001xx
SMARTsat® OEM II module	9110100001xx
SMARTsat® OEM III module	8110140011xx
SMARTsat® 6 pin sensor plug	5020660002
SMARTsat® sensor plug - PCB mounting version	10020660002
SMARTsat® sensor basic flex cable	9020522001
SMARTsat® sensor low noise flex cable	8110140014
SMARTsat® OEM I sensor low noise flex cable	12110140001
SMARTsat® EB with OEM II module	on request
SMARTsat® EB with OEM III module	on request
SMARTsat® EB 4-pin host connector	205012004

xx: Indicates customized FW versions (e.g. customized start-up settings/ Sensor ID)

8.2 Sensors and accessories

Product	Type	REF
SoftCap® SpO ₂ sensor – Large	SC7500	6020132004
SoftCap® SpO ₂ sensor – Medium	SCM7500	6020132010
SoftCap® SpO ₂ sensor – Small	SCP7500	6020132300
SoftFlap® SpO ₂ sensor	SF7500	6020132002
SoftWrap® SpO ₂ sensor	W7500	6020132006
Adult Plaster Disposable SpO ₂ Sensor	10-AP	6020131194
Paediatric Plaster Disposable SpO ₂ Sensor	10-PP	6020131197
Infant Plaster Disposable SpO ₂ Sensor	10-IP	6020131199
Neonatal Plaster Disposable SpO ₂ Sensor	10-NP	6020131201
Ear Probe SpO ₂ sensor	EP7500	6020132254
Y- SpO ₂ Sensor for Single Patient Use	Y7500	12020132001
Baby Foot Spotcheck Sensor	BF7500	14020132001
SMARTsat® Hydrogel pads	HGP7500	12020121002
SMARTsat® Hydrogel stripes	HGS7500	12020121001
Sensor extension cable 1.2m	XT6500	1020132275
Sensor extension cable 2.4m	XT6501	1020122058

Customized sensors (e.g. sensor ID or connector) possible, depending on order quantity. Contact your SMARTsat® implementation support at bluepoint for more detail.

9 Reporting of serious incidents

If there is a *serious incident* in connection with the use of this product, this should be reported.

The incident should be reported to the manufacturer and the health authority or the competent authority for the installation site of the product.

A *serious incident* is when there is a death or a temporary or permanent serious deterioration in the health of a patient, user or other person.

Send an email to the following manufacturer address: prrc@bluepoint-medical.com

When doing so, please provide the following information:

- Order number and model designation of the product as indicated on the product
- Serial number/batch number of the product
- Date of the *serious incident*
- Description of the *serious incident*, including its impact on the patient or any injury
- Your contact details (institution, address, contact name (substitute), title and phone number)

10 Revision History

Rev	Effective Date	Change description
10	2022-March-17	Update images, dimension and power consumption specifications for OEM I & OEM II with AAC; OEM III SpO2 accuracy validation results updated; Table 4 SMARTsat® performance under motions tested with FLUKE Index II SpO2 simulator updated; Product Standards section 4.8 updated; Add typical results for power consumption depending on baud and sample rate (4.1.2) Added "Response time", "Classification" and method detail for validation of low perfusion and motion performance and heart rate accuracy validation (section 7).
9	2020-Mai-20	Update according to communication protocol rev.11 [2] Update power consumption, response time and motion performance based on new FW Update images and features for Development brd, Protocol viewer and Emulator Move Host validation checklist to a separate document Correct typos and rework of complete format and chapters Move description of "wake up byte" to the Communication protocol rev.11 [2] Add: sensor BF7500, add drawings of connectors
8	2018-Apr-11	SMARTsat® EB added
7	2018-Mar-01	OEM I added, source OEM_I_supplement_Sheet.pdf 2/2017; added: OEM I Flex , Y Sensor , Hydrogel Pads+Stripes, update to communication protocol rev.9
6	2016-Nov-29	Update: Response time behavior (Figure 2-1 Table 6 p.14); Various symbols replaced by vector graphics; power specs and accuracy study Add: Status Flags (2.3): Loss of Pulse; SMARTsat® Emulator description; Communication Protocol Verification Procedure; Appendix (recommended Host actions and Protocol Verification Check List); IEC 62471 to list of standards; Parts REF 10020660002 and 6020132010; Terms and definitions, circuit example at section 4.6 Remove: OEM I
5	2016-Apr-04	Add: Emulator Tool (6.2) Corrected: FTM-107-03-L-DV instead of FTM-107-03-L-DV-S (p.22) Update: Protocol Viewer with store function (6.2)
4	2016-Mar-03	Add: Basic sensor flex cable and drawings (4.3.2, 9.2), Power consumption at different sampling rates (5.1), Safety note (4.3) Change: Specifications and name of wake-up sequence (6.3), description of Protocol Viewer (7.2), "normal time response mode to standard time response mode, Update to A_{rms} results of last Study UCSF (2.1).
3	2015-Dec-09	Add: Specifications of SMARTsat® OEM I and II module throughout document; One integration guide for all versions; Earprobe, SMARTsat® OEM II available Q1/2016, SQ indicator (2.1); Baud rate configuration (5.5); Warning to avoid undue bending of cable (2.3); summary of SpO2 / PR accuracy and detailed results based on clinical study 7/2015; add accuracy under motion (3.1); description of Protocol Viewer (7.2); Changed: Power consumption (4.1, 7); picture first page; Figure 6-5 (SMARTsat® Protocol Viewer); maximal Data Update Period to 28sec (3.2.2); part numbers (9); Description of figure 3-4: OEM I and II to OEM II and III
2	2015-May-19	Add: Reset (4.3) Change: SMARTsat® Protocol Viewer updated to current version of PC-software (Figure 6-5)
1	2015-Mar-31	Changed: Pin 3, Layout BU2 Table "Host Connector Pin Assignments (BU1 and BU2)" (3.2); Power supply requirements Table "Operating Parameters SMARTsat®" (4.1) Add: Fig. Power vs. baud (4.1); Host transmission start-up sequence(5.3); picture overview and jumper description at SMARTsat® Host PCB (6.1)
0_B	2014-Dez-19	Add: Test Method pulse rate (2.2); SpO2 Flex cable in supplied in development kit (3.3.2); Power consumption spec depending on BAUD (4.1); Footnote 4 (power at baud) (7) Change: standard pulse rate range 30-240bpm (2.2.1); rem unify product names and correct order number paediatric disposable sensor syntax correction throughout document (8.2) Remove: REF at Order numbers in chapter 8 (3.3.1), Interboard flex cable (8.1)
0	2014-Dez-15	Initial version