Pulse Oximeter Service

Bluetooth® Service Specification

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Abstract:

This Service specification defines a pulse oximetry sensor for use in consumer and professional healthcare applications.

Revision History

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Document Terminology

The Bluetooth SIG has adopted portions of the IEEE Standards Style Manual, which dictates use of the words “shall”, “should”, “may”, and “can” in the development of documentation, as follows:

The word *shall* is used to indicate mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).

The use of the word *must* is deprecated and shall not be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

The use of the word *will* is deprecated and shall not be used when stating mandatory requirements; *will* is only used in statements of fact.

The word *should* is used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in the negative form) a certain course of action is deprecated but not prohibited (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

The term *Reserved for Future Use (RFU)* is used to indicate Bluetooth SIG assigned values that are reserved by the Bluetooth SIG and are not otherwise available for use by implementations.

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1 Introduction

The Pulse Oximeter (PLX) Service exposes pulse oximetry data related to a non-invasive pulse oximetry sensor for consumer and professional healthcare applications.

1.1 Conformance

If a device claims conformance to this service, all capabilities indicated as mandatory for this service shall be supported in the specified manner (process-mandatory). This also applies for all optional and conditional capabilities for which support is indicated. All mandatory capabilities, and optional and conditional capabilities for which support is indicated, are subject to verification as part of the Bluetooth qualification program.

1.2 Service Dependencies

This service is not dependent upon any other services.

1.3 Bluetooth Specification Release Compatibility

This specification is compatible with any Bluetooth Core Specification [2] that includes the Generic Attribute Profile (GATT) portion of the core specification.

1.4 GATT Sub-Procedure Requirements

Requirements in this section represent a minimum set of requirements for a Pulse Oximeter Sensor (GATT Server). Other GATT sub-procedures may be used if supported by both Client and Server.

Table 1.1 summarizes additional GATT sub-procedure requirements beyond those required by all GATT Servers.

GATT Sub-Procedure	Requirements
Write Characteristic Value	C.1
Notifications	C.2
Indications	C.3
Read Characteristic Descriptors	M
Write Characteristic Descriptors	M

Table 1.1: *Additional GATT Sub-Procedure Requirements*

C.1: Mandatory if spot-check measurement storage is supported, otherwise optional.
C.2: Mandatory if the PLX Continuous Measurement characteristic is supported, otherwise optional.
C.3: Mandatory if the PLX Spot-check Measurement characteristic is supported, otherwise optional.

1.5 Transport Dependencies

This service may operate over the LE or BR/EDR transports.

Where the term BR/EDR is used throughout this document, this also includes the optional use of AMP.

1.6 Application Error Codes

This service does not define any Attribute Protocol Application Error codes.

1.7 Byte Transmission Order

All characteristics used with this service shall be transmitted with the least significant octet first (i.e. little endian). The least significant octet is identified in the characteristic definitions in [3] and where characteristics are defined in Section 3.

2 Service Requirements

2.1 Declaration

The Pulse Oximeter Service is recommended to be instantiated as a «Primary Service».

The service UUID shall be set to the UUID value assigned to «Pulse Oximeter Service» defined in [3].

3 Characteristic Behaviors

This section describes the behaviors associated with each of the characteristics that make up the service.

The characteristic requirements in an instance of the Pulse Oximeter Service are shown in Table 3.1. Unless otherwise specified, only one instance of each characteristic is permitted within this service.

Characteristic Name	Requirement	Mandatory Properties	Security Permissions
PLX Spot-check Measurement	C.1	Indicate	None
PLX Continuous Measurement	C.1	Notify	None
PLX Features	M	Read	None
Record Access Control Point	C.2	Indicate, Write	None

Table 3.1: *Pulse Oximeter Service Characteristics*

C.1: Mandatory to support at least one of these characteristics.

C.2: Mandatory if measurement storage is supported for Spot-check measurements.

Note 1: Properties not listed as Mandatory or Conditional are Excluded.

Note 2: Security Permissions of “None” means that this service does not impose any requirements.

Note 3: Where a characteristic can be indicated and/or notified, a Client Characteristic Configuration descriptor shall be included in that characteristic as required by the Core Specification [2].

3.1 PLX Spot-Check Measurement

The PLX Spot-check Measurement characteristic, if supported, shall be used to send Spot-check measurements of SpO2 (Percent oxygen saturation of hemoglobin) and PR (pulse rate).

Included in the characteristic are the Flags field, the SpO2PR-Spot-Check field, and depending on the contents of the Flags field, the Timestamp field, the Measurement Status field, the Device and Sensor Status field, and/or the Pulse Amplitude Index field. These fields are shown in Table 3.2.

LSO MSO

	Flags	SpO2PR-Spot-Check		Timestamp (if present)	Measurement Status (if present)	Device and Sensor Status (if present)	Pulse Amplitude Index (if present)
		SpO2	PR				
Octet Order	N/A	LSO..MSO	LSO..MSO	LSO..MSO	LSO..MSO	LSO..MSO	LSO..MSO
Data Type	8bit	SFLOAT	SFLOAT	Date time characteristic, Defined in [3]	16bit	24bit	SFLOAT
Size	1 octet	2 octets	2 octets	0 or 7 octets	0 or 2 octets	0 or 3 octets	0 or 2 octets
Units	None	Percentage	period (beats per minute)	Smallest unit in seconds	None	None	Percentage

Table 3.2: *PLX Spot-check Measurement Characteristic fields*

Where LSO = Least Significant Octet and MSO = Most Significant Octet

3.1.1 Characteristic Behavior*:*

The PLX Spot-check Measurement characteristic is identified using the UUID «PLX Spot-check Measurement»

Measurement Generation:

A Spot-check measurement is a single measurement that is generated once per measurement session to give a discrete reading of a patient's oximetry status. In the context of this service, a measurement session is the entire time the device is 'on', e.g. the entire time it is attempting to take measurements, or the entire time power is applied to the pulse oximeter, etc.

For example, a typical Spot-check measurement scenario is that the user would place a pulse oximeter on their finger, the oximeter would start acquiring measurements, and once the measurement results were stable, it would send one oximetry measurement indication to the user's smartphone. The user would then remove the oximeter from their finger.

The amount of time an oximeter takes to generate a stable measurement varies by implementation. Some oximeters will use the first measurement the sensor can get, whereas others will use a fixed stabilization period, and others use more complex algorithms.

A measurement that is considered stable can also be considered 'fully qualified', meaning that the measurement has met all implementation-specific criteria for stability and/or quality. The server shall indicate this condition using the "Fully Qualified Data" bit in the Measurement Status field of the characteristic value (see Section 3.1.1.4) if the field and bit is supported.

If the pulse oximeter cannot generate a stable, fully qualified measurement due to physiological or environmental factors, the Server may indicate this characteristic after a timeout instead (typically about 40 seconds - the timeout period is left to the implementation).

New Measurement:

This characteristic shall indicate a 'new' measurement once per measurement session.

When a spot-check measurement has been generated and if a connection is not currently established, the Server shall become connectable to allow the Client to create a link.

If the new measurement is not transmitted successfully to a Client during the measurement session (such as when a connection is never made or the characteristic cannot be successfully indicated while in a connection), and the Server supports measurement storage, the measurement shall be temporarily stored for later transmission using the Record Access Control Point's (RACP's) Report Stored Records Procedure (see Section 3.4.4). If measurement storage is not supported, the Server shall discard the measurement at the end of the measurement session. A measurement shall only be successfully transmitted once.

If the PLX Continuous Measurement characteristic (see Section 3.2) is not supported or is not configured for notifications (i.e. the characteristic is not being used), the Server may end the connection once the new Spot-check measurement has been indicated. However, the Server should remain connected for at least 15 seconds to allow a Client to perform any needed RACP procedures on the Server or interact with any other services that perform actions such as setting the time.

The PLX Spot-check Measurement characteristic contains time-sensitive data, thus the requirements for time-sensitive data and data storage defined in Section 3.5 apply.

If the new measurement is generated by the Server while a Report Stored Records Procedure is in progress, the new measurement shall be indicated after the procedure has been completed.

Stored Measurements:

The Server shall transmit stored measurements using the Report Stored Records Procedure (see Section 3.4.4).

3.1.1.1 Flags Field

The Flags field shall be included in the PLX Spot-check Measurement characteristic.

The Flags field is an 8-bit bit field which indicates what fields are present in the PLX Spot-check Measurement Characteristic value. This field also indicates if the clock was not set for the measurement being reported.

Reserved for Future Use (RFU) bits in the Flags field shall be set to 0.

The format of the Flags field is defined in Table 3.3:

Bit	Definition
0	Timestamp field is present
1	Measurement Status field is present
2	Device and Sensor Status field is present
3	Pulse Amplitude Index field is present
4	Device Clock is Not Set
5-7	Reserved for Future Use

Table 3.3: *PLX Spot-check Measurement Characteristic Flags*

3.1.1.2 SpO2PR-Spot-Check Field

The SpO2PR-Spot-Check field shall be included in the PLX Spot-check Measurement characteristic.

The SpO2PR-Spot-Check field is composed of two subfields: SpO2 and PR (pulse rate).

If a value for SpO2 or PR is unavailable (e.g. due to a measurement or device error), the special short float value NaN (Not a Number) (see Section 5.1) shall be used in the unavailable subfield(s).

3.1.1.3 Timestamp Field

The Timestamp field shall be included in the PLX Spot-check Measurement characteristic if the Server supports storing Spot-check measurements. Otherwise, it is optional.

If the Timestamp field is supported, the Server shall set the “Timestamp field is present” bit of the Flags field to 1 and include the Timestamp field. If the Timestamp is not supported, the Server shall set the “Timestamp field is present” bit of the Flags field to 0 and not include the Timestamp field.

The date and time of the device may be updated by various means such as via a simple user interface on the device, via an external time service, etc.

The time stamp shall use the same format as the Date Time characteristic defined in [3].

3.1.1.4 Measurement Status Field

If the Measurement Status field is present in the PLX Spot-check Measurement characteristic, the “Measurement Status field is present“ bit of the Flags field shall be set to 1; otherwise it shall be set to 0.

Reserved for Future Use (RFU) bits in the Measurement Status field shall be set to 0.

Support for each bit of the Measurement Status field is specified in the PLX Features characteristic’s Measurement Status Support field (see Section 3.3.1.2). If the bit is not supported, it shall always be set to 0 in the Measurement Status field of this characteristic.

For any bit that is supported, a value of 1 shall indicate that the status the bit reports is true, and 0 shall indicate false.

Each supported bit is mapped directly to the MeasurementStatus attribute in ISO/IEEE 11073-20601 [4], with two exceptions. This allows for easy transcoding and common definitions (see [6]).

The exceptions are two additional bits that add useful information to the field in this specification

- The “Data from Measurement Storage” bit is used to indicate that the measurement is a temporarily stored measurement.
- The “Fully Qualified Data” bit is used to indicate that the measurement meets the “fully qualified” criteria described in Section 3.1.

The format of the Measurement Status field is defined in *Table 3.4*.

Bit	Definition
0-4	Reserved for Future Use
5	Measurement Ongoing
6	Early Estimated Data
7	Validated Data
8	Fully Qualified Data
9	Data from Measurement Storage
10	Data for Demonstration
11	Data for Testing
12	Calibration Ongoing
13	Measurement Unavailable
14	Questionable Measurement Detected
15	Invalid Measurement Detected

Table 3.4: *Measurement Status definitions*

3.1.1.5 Device and Sensor Status Field

If the Device and Sensor Status field is present in the PLX Spot-check Measurement characteristic, the “Device and Sensor Status field is present” bit of the Flags field shall be set to 1; otherwise it shall be set to 0.

Reserved for Future Use (RFU) bits in the Device and Sensor Status field shall be set to 0.

Support for each bit of the Device and Sensor Status field is specified in the PLX Features characteristic’s Device and Sensor Status Support field (see Section 3.3.1.3). If the bit is not supported, it shall always be set to 0 in the Device and Sensor Status field of this characteristic.

For any bit that is supported, a value of 1 shall indicate that the status the bit reports is true, and 0 shall indicate false.

Each supported bit is mapped directly to the Device and Sensor Status attribute in ISO/IEEE 11073-10404 [5]. This allows for easy transcoding and common definitions.

The format of the Device and Sensor Status field is defined in Table 3.5.

Bit	Definition
0	Extended Display Update Ongoing
1	Equipment Malfunction Detected
2	Signal Processing Irregularity Detected
3	Inadequate Signal Detected
4	Poor Signal Detected
5	Low Perfusion Detected
6	Erratic Signal Detected
7	Non-Pulsatile Signal Detected
8	Questionable Pulse Detected
9	Signal Analysis Ongoing
10	Sensor Interference Detected
11	Sensor Unconnected to User
12	Unknown Sensor Connected
13	Sensor Displaced
14	Sensor Malfunctioning
15	Sensor Disconnected
16-23	Reserved for Future Use

Table 3.5: *Device and Sensor Status definitions*

3.1.1.6 Pulse Amplitude Index

The Pulse Amplitude Index is a percentage indicator indicating the perfusion level (amount of blood being delivered to the capillary bed) of a user.

If the Pulse Amplitude Index field is present in the PLX Spot-check Measurement characteristic, “Pulse Amplitude Index field is present” bit of the Flags field shall be set to 1; otherwise it shall be set to 0.

If a value for the pulse amplitude index is unavailable (e.g. due to a measurement or device error), the special short float value NaN (see Section 5.1) shall be used in the unavailable subfield(s).

3.2 PLX Continuous Measurement Characteristic

The PLX Continuous Measurement characteristic, if supported, shall be used to send periodic pulse oximetry measurements.

Included in the characteristic are the Flags field (to indicate presence of optional fields), the SpO2PR-Normal field, and depending on the contents of the Flags field, the SpO2PR-Fast field, the SpO2PR-Slow field, the Measurement Status field, the Device and Sensor Status field, and/or the Pulse Amplitude Index field.

LSO

	Flags	**SpO2PR-Normal**		**SpO2PR-Fast (if present)**		**SpO2PR-Slow (if present)**	
		SpO2	**PR**	**SpO2**	**PR**	**SpO2**	**PR**
Octet Order	N/A	LSO..MSO	LSO..MSO	LSO..MSO	LSO..MSO	LSO..MSO	LSO..MSO
Data Type	8bit	SFLOAT	SFLOAT	SFLOAT	SFLOAT	SFLOAT	SFLOAT
Size	1 octet	2 octets	2 octets	0 or 2 octets	0 or 2 octets	0 or 2 octets	0 or 2 octets
Units	None	Percentage	period (beats per minute)	Percentage	period (beats per minute)	Percentage	period (beats per minute)

MSO

	Measurement Status (if present)	Device and Sensor Status (if present)	Pulse Amplitude Index (if present)
Octet Order	LSO..MSO	LSO..MSO	LSO…MSO
Data Type	16bit	24bit	SFLOAT
Size	0 or 2 octets	0 or 3 octets	0 or 2 octets
Units	None	None	Percentage

Table 3.6: *PLX Continuous Measurement Characteristic fields*

Where LSO = Least Significant Octet, MSO = Most Significant Octet and PR = Pulse Rate

3.2.1 Characteristic Behavior

A Continuous measurement is a periodically updated oximetry measurement that is generated repeatedly until a connection is terminated, typically sending a notification at a period of 1-4 seconds.

The PLX Continuous Measurement Characteristic is identified using the UUID «PLX Continuous Measurement», as defined in [3]. When the *Client Characteristic Configuration* descriptor is configured for notifications, this characteristic shall be notified periodically while in a connection.

The notifications of this characteristic are meant to be transmitted immediately, and no timestamping or temporary storage is provided by this service (also see Section 3.5).

If a notification is available and a connection is not currently established, the Server should become connectable to allow the Client to create a link.

3.2.1.1 Flags Field

The Flags field shall be included in the PLX Continuous Measurement characteristic.

The Flags field is an 8-bit bit field which indicates what fields are present in the PLX Continuous Measurement Characteristic value.

Reserved for Future Use (RFU) bits in the Flags field shall be set to 0.

The format of the Flags field is defined in Table 3.7.

Bit	Definition
0	SpO2PR–Fast field is present
1	SpO2PR-Slow field is present
2	Measurement Status field is present
3	Device and Sensor Status field is present
4	Pulse Amplitude Index field is present
5-7	Reserved for Future Use

Table 3.7: *PLX Continuous Measurement Characteristic Flags*

3.2.1.2 SpO2PR-Normal Field

The SpO2PR-Normal field shall be included in the PLX Continuous Measurement characteristic.

The SpO2PR-Normal field is composed of two subfields: SpO2 and PR (pulse rate).

If a value for SpO2 or PR is unavailable (e.g. due to a measurement or device error), the special short float value NaN (see Section 5.1) shall be used in the unavailable subfield(s).

3.2.1.3 SpO2PR-Fast Field

The SpO2PR-Fast field shall be included in the PLX Continuous Measurement characteristic if the Server supports the SpO2PR-Fast metric; otherwise, it shall be excluded.

The SpO2PR-Fast field is composed of two subfields: SpO2 and PR (pulse rate).

If the SpO2PR-Fast field is present in the PLX Continuous Measurement characteristic, the "SpO2PR–Fast field is present" bit of the Flags field shall be set to 1; otherwise it shall be set to 0 and the SpO2PR-Fast field shall not be present.

The SpO2PR-Fast field reports fast responding oximetry measurements of the sensor. Signal processing algorithms better at highlighting quick changes in oximetry data are typically used to generate this data.

If a value for fast responding SpO2 or PR is unavailable (e.g. due to a measurement or device error), the special short float value NaN (see Section 5.1) shall be used in the unavailable subfield(s).

3.2.1.4 SpO2PR-Slow Field

The SpO2PR-Slow field shall be included in the PLX Continuous Measurement characteristic if the Server supports the SpO2PR-Slow metric; otherwise, it shall be excluded.

The SpO2PR-Slow field is composed of two subfields: SpO2 and PR (pulse rate).

If the SpO2PR-Slow field is present in the PLX Continuous Measurement characteristic, the "SpO2PR–Slow field is present" bit of the Flags field shall be set to 1; otherwise it shall be set to 0 and the SpO2PR-Slow field shall not be present.

The SpO2PR-Slow field reports slow responding oximetry measurements of the sensor. Signal processing algorithms better at eliminating changes to oximetry measurements due to motion are typically used to generate this data.

If a value for slow responding SpO2 or PR is unavailable (e.g. due to a measurement or device error), the special short float value NaN (see Section 5.1) shall be used in the unavailable subfield(s).

3.2.1.5 Measurement Status Field

The Measurement Status field shall be included in the PLX Continuous Measurement characteristic if the device supports measurement status flags; otherwise, it shall be excluded.

If the Measurement Status field is present in the PLX Continuous Measurement characteristic, the “Measurement Status field is present” bit of the Flags field shall be set to 1; otherwise it shall be set to 0 and the Measurement Status field shall not be present.

Reserved for Future Use (RFU) bits in the Measurement Status field shall be set to 0.

Support for each bit of the Measurement Status field is specified in the PLX Features characteristic’s Measurement Status Support field (see Section 3.3.1.2). If the bit is not supported, it shall always be set to 0 in the Measurement Status field of this characteristic.

The Measurement Status bit definitions are the same as in Section 3.1.1.4.

3.2.1.6 Device and Sensor Status Field

The Device and Sensor Status field shall be included in the PLX Continuous Measurement characteristic if the device supports device and sensor status flags; otherwise, it shall be excluded.

If the Device and Sensor Status field is present in the PLX Continuous Measurement characteristic, the “Device and Sensor Status field is present” bit of the Flags field shall be set to 1; otherwise it shall be set to 0 and the Device and Sensor Status field shall not be present.

Reserved for Future Use (RFU) bits in the Device and Sensor Status field shall be set to 0.

Support for each bit of the Device and Sensor Status field is specified in the PLX Features characteristic’s Device and Sensor Status Support field (see Section 3.3.1.3). If the bit is not supported, it shall always be set to 0 in the Device and Sensor Status field of this characteristic.

The Device and Sensor Status bit definitions are the same as in Section 3.1.1.5.

3.2.1.7 Pulse Amplitude Index

The Pulse Amplitude Index field shall be included in the PLX Continuous Measurement characteristic if the device supports the Pulse Amplitude Index field, otherwise it shall be excluded.

If the Pulse Amplitude Index field is present in the PLX Continuous Measurement characteristic, “Pulse Amplitude Index field is present” bit of the Flags field shall be set to 1; otherwise it shall be set to 0.

If a value for the pulse amplitude index is unavailable (e.g. due to a measurement or device error), the special short float value NaN (see Section 5.1) shall be used in the unavailable subfield(s).

3.3 PLX Features

The PLX Features characteristic shall be used to describe the supported features of the Server.

Support for this characteristic is mandatory.

The PLX Features Characteristic is identified using the UUID «PLX Features», as defined in [3].

Included in the characteristic is a PLX Features field, and, depending on the contents of the PLX Features field, the Measurement Status Support field, and the Device and Sensor Status Support field. These fields are shown in Table 3.8.

LSO MSO

	Supported Features	Measurement Status Support (if present)	Device and Sensor Status Support (if present)
Octet Order	LSO..MSO	LSO..MSO	LSO..MSO
Data Type	16bit	16bit	24bit
Size	2 octets	0 or 2 octets	0 or 3 octets
Units	None	None	None

***Table 3.8:** PLX Features Characteristic fields*

3.3.1 Characteristic Behavior

When read, the PLX Features characteristic returns a value that is used by a Client to determine the supported features of the Server.

All bits of the PLX Features characteristic shall be static for the lifetime of the device (i.e. static permanently or until Service Changed is indicated).

3.3.1.1 Supported Features Field

The Supported Features field shall be included in the PLX Features characteristic.

The Supported Features field is a 16-bit bit field which indicates feature support as well as what fields are present in the PLX Features characteristic.

Reserved for Future Use (RFU) bits in the Supported Features field shall be set to 0.

The format of the Supported Features field is defined in Table 3.9:

Bit	Definition
0	Measurement Status support is present
1	Device and Sensor Status support is present
2	Measurement Storage for Spot-check measurements is supported
3	Timestamp for Spot-check measurements is supported
4	SpO2PR-Fast metric is supported
5	SpO2PR-Slow metric is supported
6	Pulse Amplitude Index field is supported
7	Multiple Bonds Supported
8-15	Reserved for Future Use

Table 3.9: *Supported Features Field*

3.3.1.1.1 Measurement Status Support Bit:

If the “Measurement Status Supported” bit is set to 1:

- The Measurement Status feature is supported.
- The Measurement Status Support field in this characteristic shall be present.
- The Measurement Status field shall be present when the PLX Spot-check Measurement characteristic is indicated.
- The Measurement Status field shall be present when the PLX Continuous Measurement characteristic is notified.

If the “Measurement Status Supported” bit is set to 0:

- The Measurement Status feature is not supported.
- The Measurement Status Support field in this characteristic shall not be present.
- The Measurement Status field shall not be present when the PLX Spot-check Measurement characteristic is indicated.
- The Measurement Status field shall not be present when the PLX Continuous Measurement characteristic is notified.

3.3.1.1.2 Device and Sensor Status Support Bit:

If the “Device and Sensor Status Supported” bit is set to 1:

- The Device and Sensor Status Feature is supported.
- The Device and Sensor Status Support field in this characteristic shall be present.

- The Device and Sensor Status field shall be present when the PLX Spot-check Measurement characteristic is indicated.
- The Device and Sensor Status field shall be present when the PLX Continuous Measurement characteristic is notified.

If the “Device and Sensor Status Supported” bit is set to 0:

- The Device and Sensor Status feature is not supported.
- The Device and Sensor Status Support field in this characteristic shall not be present.
- The Device and Sensor Status field shall not be present when the PLX Spot-check Measurement characteristic is indicated.
- The Device and Sensor Status field shall not be present when the PLX Continuous Measurement characteristic is notified.

3.3.1.1.3 Measurement Storage for Spot-check measurements is supported Bit:

If the “Measurement Storage for Spot-check measurements is supported” bit is set to 1:

- The Record Access Control Point characteristic shall be present.
- The PLX Spot-check Measurement characteristic shall include the timestamp field when it is indicated.
- The “Timestamp for Spot-check measurements is supported” bit in this field shall be set to 1.
- The Server shall have a means of setting its clock.

If the “Measurement Storage for Spot-check measurements is supported” bit is set to 0:

- The Server shall not store Spot-check measurements.

3.3.1.1.4 Other Bits:

If the “Timestamp for Spot-check measurements is supported” bit is set to 1, the Timestamp field shall be included when the PLX Spot-check Measurement characteristic is indicated, otherwise it shall not be present.

If the “SpO2PR-Fast metric is supported” bit is set to 1, the SpO2PR-Fast metric shall be included when the PLX Continuous Measurement characteristic is notified, otherwise it shall not be present.

If the “SpO2PR-Slow metric is supported” bit is set to 1, the SpO2PR-Slow metric shall be included when the PLX Continuous Measurement characteristic is notified, otherwise it shall not be present.

If the “Pulse Amplitude Index field is supported” bit is set to 1, the Pulse Amplitude Index field shall be included when the PLX Continuous Measurement characteristic is notified or the PLX Spot-Check Measurement characteristic is indicated. Otherwise it shall not be present.

If the Multiple Bonds feature is supported, the “Multiple Bonds Supported Feature” bit shall be set to 1, otherwise it shall be set to 0.

3.3.1.2 Measurement Status Support Field

The Measurement Status Support field shall be included in the PLX Features characteristic if the Measurement Status feature is supported (see Section 3.3.1.1.1); otherwise, it shall be excluded.

Reserved for Future Use (RFU) bits in the Measurement Status Support field shall be set to 0.

If the bit for a field is set to 1, the bit is supported when it is sent in a measurement transmission. If the bit is set to 0, the bit is not supported and shall never be set to 1 wherever a Measurement Status field is present.

The bits of the Measurement Status Support field are defined in Table 3.10.

Bit	Definition
0-4	Reserved for Future Use
5	Measurement Ongoing bit supported
6	Early Estimated Data bit supported
7	Validated Data bit supported
8	Fully Qualified Data bit supported
9	Data from Measurement Storage bit supported
10	Data for Demonstration bit supported
11	Data for Testing bit supported
12	Calibration Ongoing bit supported
13	Measurement Unavailable bit supported
14	Questionable Measurement Detected bit supported
15	Invalid Measurement Detected bit supported

Table 3.10: *Measurement Status Support definition*

3.3.1.3 Device and Sensor Status Support Field

The Device and Sensor Status Support field shall be included in the PLX Features characteristic if the Device and Sensor Status feature is supported (see Section 3.3.1.1.2); otherwise, it shall be excluded.

If the bit for a field is set to 1, the bit is supported when it is sent in a measurement transmission. If the bit is set to 0, the bit is not supported and shall never be set to 1 wherever a Device and Sensor Status field is present.

Reserved for Future Use (RFU) bits in the Device and Sensor Status Support field shall be set to 0.

The bits of the Device and Sensor Status Support field are defined in Table 3.11.

Bit	Definition
0	Extended Display Update Ongoing bit supported
1	Equipment Malfunction Detected bit supported
2	Signal Processing Irregularity Detected bit supported
3	Inadequate Signal Detected bit supported
4	Poor Signal Detected bit supported
5	Low Perfusion Detected bit supported
6	Erratic Signal Detected bit supported
7	Nonpulsatile Signal Detected bit supported
8	Questionable Pulse Detected bit supported
9	Signal Analysis Ongoing bit supported
10	Sensor Interference Detected bit supported
11	Sensor Unconnected to User bit supported
12	Unknown Sensor Connected bit supported
13	Sensor Displaced bit supported
14	Sensor Malfunctioning bit supported
15	Sensor Disconnected bit supported
16-23	Reserved for Future Use

Table 3.11: *Device and Sensor Status Support definition*

3.4 Record Access Control Point

[1] For this service to operate, profiles or other applications utilizing this service will need to ensure that the Client configures the Record Access Control Point (RACP) [3] characteristic for indications.

When a client performs a write to the RACP to execute a desired procedure at the Server response shall be sent from the Server in an indication.

3.4.1 Record Definition

Within the context of the Pulse Oximeter Service, a record consists of a temporarily stored, timestamped PLX Spot-check Measurement Characteristic value, according to Section 3.1.

3.4.2 RACP Procedure Requirements

The table below shows the requirements for the RACP procedures (Op Codes, Operators, and Operands) in the context of this service (see [3] for op code, operator, and operand values of the RACP).

Procedure/ Op Code	Op Code Requirement	Operator	Operator Requirement	Operand	Operand Requirement
Report Stored Records	M	All records	M	No Operand Used	N/A
Delete Stored Records	O	All records	C	No Operand Used	N/A
Abort Operation	O	Null (0x00)	C	No Operand Used	N/A
Report Number of Stored Records	O	All records	C	No Operand Used	N/A
Responses					
Procedure/ Op Code	**Op Code Requirement**	**Operator**	**Operator Requirement**	**Operand**	**Operand Requirement**
Number of Stored Records Response	O	Null (0x00)	C	UINT16 containing number of records	M
Response Code	M	Null (0x00)	M	Request Op Code, Response Code Value	M

Table 3.12: *RACP Procedure Requirements*

C Mandatory if associated Op Code is supported, otherwise optional.

Notes:

1. Support for a given Operand for one Op Code and Operator combination does not imply support of that Operand for other Op Code and Operator combinations.
2. Support for a given Operator for one Op Code does not imply support of that Operator for other Op Codes.
3. Op Codes that are not shown in Table 3.12 are excluded from support in this service.

3.4.3 Record Access Control Point Behavioral Description

The Record Access Control Point shall be used to control indications for stored records of the PLX Spot-Check Measurement characteristic, as well as perform actions related to stored records, such as deleting them. Procedures are triggered by a Write to this characteristic value that includes an Op Code specifying the operation (see Table 3.12). In a multiple-bond case, the handling of the Control Point shall be consistent across all bonds, i.e. there is a single database that is shared by all Clients.

3.4.4 Report Stored Records Procedure

When the *Report Stored Records* Op Code is written to the Record Access Control Point, the Server shall indicate stored records using the PLX Spot-check measurement characteristic. Once all data records for a given request have been indicated by the Server, the Server shall indicate the Record Access Control Point with a *Response Code* Op Code and *Response Code Value* in the Operand set to *Success* (see Record Access Control Point in [3]).

If the Server does not locate any records of the type requested available, the Server shall indicate the Record Access Control Point with a *Response Code* Op Code and *Response Code Value* in the Operand set to *No Records Found* (see RACP in [3]).

If the operation results in an error condition, this shall be indicated using the *Response Code* Op Code and the appropriate *Response Code Value* in the Operand for the error condition (see Section 3.4.8).

If the Server is required to interrupt its data transfer before completion for any reason except in the event of an Abort Operation request, the Server shall indicate the Record Access Control Point with a *Response Code* Op Code and *Response Code Value* in the Operand set to *Procedure not completed* (see RACP in [3]). In the event of an Abort Operation command, the procedure terminates immediately without the RACP indicating the *Response Code* Op Code for this procedure.

If this procedure is not completed, all records that had been successfully transmitted (i.e. *ATT_Handle_Value_Confirmation* is received) up until the procedure failure shall be considered successfully transmitted and any that have been successfully indicated shall not be transmitted again in subsequent Report Stored Records procedures.

3.4.5 Delete Stored Records procedure

When the *Delete Stored Records* Op Code is written to the Record Access Control Point, the Server shall delete all stored measurements. Deletion of records may be a permanent deletion of records from the patient database. The Server shall indicate this characteristic with a *Response Code Value* of *Success* if the records were successfully deleted from the patient record database (see RACP in [3]).

If the operation results in an error condition, this shall be indicated using the *Response Code* Op Code and the appropriate *Response Code Value* in the Operand for the error condition (see Section 3.4.8).

3.4.6 Abort Operation procedure

When the *Abort Operation* Op Code is written to the Record Access Control Point, the Server shall stop any RACP procedures currently in progress and shall make a best effort to stop sending any further data.

Once all RACP procedures have been stopped, the Server shall indicate the Record Access Control Point with a *Response Code* Op Code and *Response Code Value* in the Operand set to *Success* (see RACP in [3]).

If the operation results in an error condition, this shall be indicated using the *Response Code* Op Code and the appropriate *Response Code Value* in the Operand for the error condition (see Section 3.4.8).

3.4.7 Report Number of Stored Records procedure

When the *Report Number of Stored Records* Op Code is written to the Record Access Control Point, the Server shall calculate and respond with a record count in UINT16 format. The response is indicated using the *Number of Stored Records Response* Op Code.

If the operation results in an error condition, this shall be indicated using the *Response Code* Op Code and the appropriate *Response Code Value* in the Operand for the error condition (see Section 3.4.8).

3.4.8 RACP Specific Errors

If the Server is unable to complete a procedure for any reason not stated here, the Server shall indicate the RACP with a *Response Code* Op Code and *Response Code Value* in the Operand set to *Procedure not completed* (see RACP in [3]).

If the Server is unable to process the Abort Operation procedure for any reason not stated here, the Server shall indicate the RACP with a *Response Code* Op Code and *Response Code Value* in the Operand set to *Abort unsuccessful* (see RACP in [3]).

If a request with an Op Code other than *Abort Operation* is written to the RACP while the Server is performing a previously triggered RACP operation (i.e. resulting from invalid Client behavior), the Server shall return an error response with the Common Profile and Service error code of *Procedure Already In Progress* (see [2]).

If the Op Code that was written to the RACP requests record indications and the Client Characteristic Configuration descriptor is not configured for indications, the Server shall return an error response with Common Profile and Service error code of *Client Characteristic Configuration Descriptor Improperly Configured* (see [2]).

If the Operator that was written to the RACP is not supported by the Server, the Server shall indicate the RACP with a *Response Code* Op Code and *Response Code Value* in the Operand set to *Operator Not Supported* (see RACP in [3]).

If the Operator that was written to the RACP is invalid, the Server shall indicate the RACP with a *Response Code* Op Code and *Response Code Value* in the Operand set to *Invalid Operator* (see RACP in [3]).

If the Op Code that was written to the RACP characteristic is not supported by the Server, the Server shall indicate the RACP with a *Response Code* Op Code and *Response Code Value* in the Operand set to *Op Code Not Supported* (see RACP in [3]).

If an Operand that was written to the RACP characteristic is not supported by the Server, the Server shall indicate the RACP with a *Response Code* Op Code and *Response Code Value* in the Operand set to *Operand Not Supported* (see RACP in [3]).

3.4.9 Procedure Timeout and Failure

In the context of the RACP characteristic, a procedure is started when a write to the RACP characteristic is successfully completed. When a procedure is complete, the Server indicates the RACP characteristic with the Op Code set to the corresponding *Response Code*.

A RACP procedure may consist of multiple characteristic indications of the PLX Spot-check Characteristic value followed by an indication of the RACP. Time between these indications shall not exceed a 5 second timeout period. If a timeout occurs, the Server shall stop sending any further indications related to the operation and consider the procedure to have failed.

If the connection to the Client is lost, the procedure shall be considered to have failed, and shall not resume upon the next connection.

3.5 Requirements for Time-Sensitive Data

The PLX Spot-check Measurement characteristic value contains time-sensitive data and is considered a time-sensitive characteristic.

For this characteristic, the following requirements apply:

- If the Server supports measurement storage:
  - The Server should be able to store 30 or more measurements.
  - The PLX Spot-check Measurement characteristic value shall include the Timestamp field.
  - Support for the Timestamp field shall be expressed in the PLX Features characteristic value.
  - If the maximum storage capacity in the Server is reached, the Server should overwrite the oldest stored measurements first when acquiring new measurements.
  - When indicating stored data, the oldest data shall be sent first followed by the next oldest data (in first-in, first-out order) until all stored data has been transferred.
  - The Server's date and time may be lost due to battery replacement. If the Client can set the date and time, it is recommended that the Client ensures the date and time is valid at the start of each connection. If the time of the device is not set and new measurements are generated, the Flags field in the PLX Spot-check Measurement characteristic value (see Section 3.1.1.1) shall indicate the clock is not set for the measurement and the Client may check the Server's time if it is available and calculate what the correct time of the measurement is based on the

difference. Temporarily stored measurements may be discarded when a battery replacement occurs.

- If the Server does not support measurement storage:
  - A measurement that is not indicated within the same measurement session it was generated in shall be discarded.

Note: If a pulse oximeter is designed to store periodic measurements for transmission later, e.g. in a sleep study, this service does not provide that functionality. Those features could be handled by another service in the profile that would use an efficient design for the transfer of large amounts of data.

The PLX Continuous Measurement characteristic is meant to provide periodic live measurements, but is not optimal for transmitting large volumes of stored records of this characteristic. Therefore, it is only used to send live measurements that are not stored, although the stored measurements may be very similar in format and period.

4 SDP Interoperability

If this service is exposed over BR/EDR then it shall have the following SDP record.

Item	Definition	Type	Value	Status
Service Class ID List				M
Service Class #0		UUID	«Pulse Oximeter Service»	M
Protocol Descriptor List				M
Protocol #0		UUID	L2CAP	M
Parameter #0 for Protocol #0	PSM	Uint16	PSM = ATT	M
Protocol #1		UUID	ATT	M
Parameter #0 for Protocol #1	GATT Start Handle	Uint16	First handle of this service in the GATT database	M
Parameter #1 for Protocol #1	GATT End Handle	Uint16	Last handle of this service in the GATT database	M
BrowseGroupList			PublicBrowseRoot*	M

Table 4.1: *SDP Record*

* PublicBrowseRoot shall be present; however, other browse UUIDs may also be included in the list.

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5 Special Values

5.1 Special Short Float Value

The following special short float values are defined in IEEE 11073-20601 [4].

Special Short Value	Value
NaN (not a number)	0x07FF
NRes (not at this resolution)	0x0800
+ INFINITY	0x07FE
- INFINITY	0x0802
Reserved for future use	0x0801

Table 5.1: *Special Short Float Values*

NaN is used to report an invalid result from a computation step or to indicate missing data due to the hardware's inability to provide a valid measurement, perhaps from sensor perturbation.

NRes is used to report that the value cannot be represented with the available range and resolution, possibly resulting from an overflow or underflow situation.

6 Acronyms and Abbreviations

Any abbreviation or acronym used in the document, but not defined in the Bluetooth Core Specification [2] sections (e.g., Volume 1 Part B), is defined here. The list is alphabetized.

Abbreviation or Acronym	Meaning
PR	Pulse Rate
PLX	Pulse Oximeter
RACP	Record Access Control Point
SpO2	Percent oxygen saturation of hemoglobin, as measured by a pulse oximeter.

Table 6.1: *Abbreviations and Acronyms*

7 References

[2] Bluetooth Core Specification, Version 4.0 (as amended by CSS v4) or later

[3] Characteristic and Descriptor descriptions and UUIDs are accessible via the Bluetooth SIG Assigned Numbers

[4] ISO/IEEE Std 11073-20601™- 2008 Health Informatics - Personal Health Device Communication - Application Profile - Optimized Exchange Protocol - version 1.0 or later. This also includes ISO/IEEE Std 11073-20601a™- 2010 – Amendment 1.

[5] ISO/IEEE Std 11073-10404™ – 2008 – Health Informatics – Personal Health Device Communication – Part 10404: Device specialization – Pulse Oximeter

[6] Personal Health Devices Transcoding White Paper v1.TBD or later