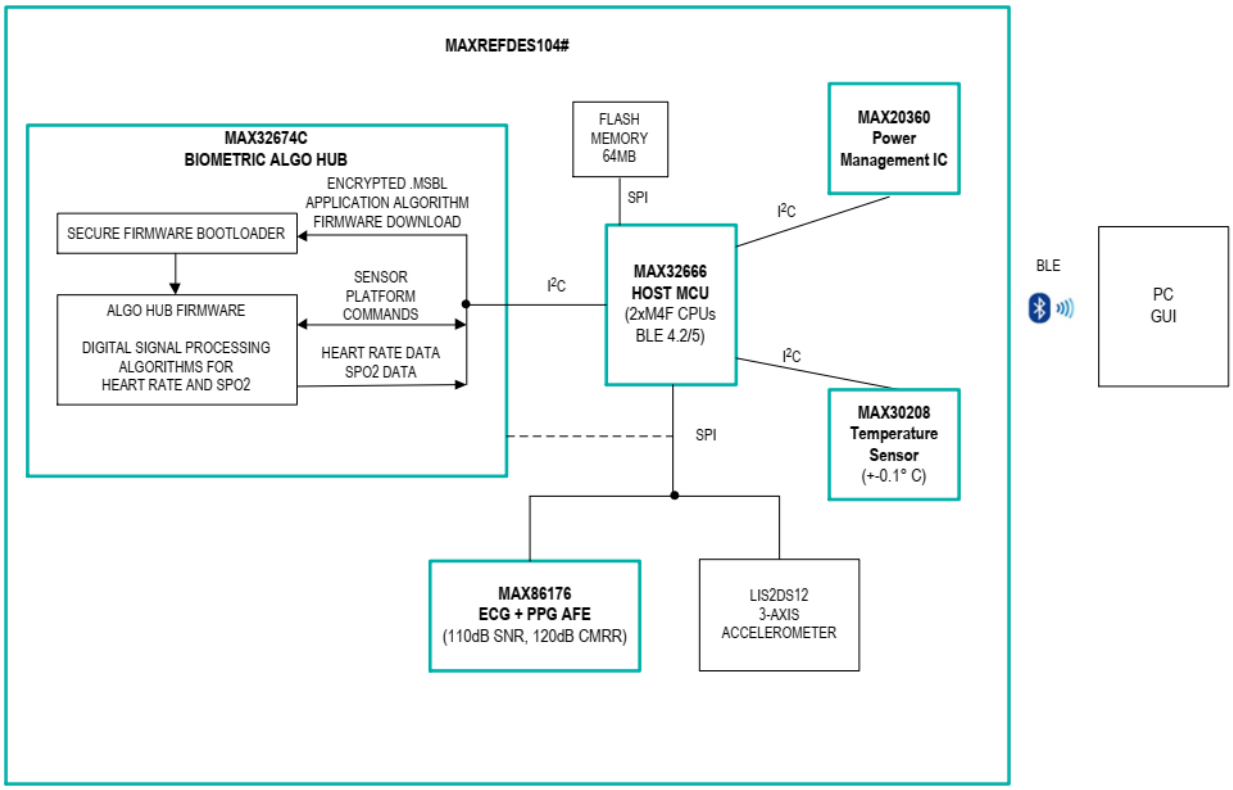
MAXREFDES104 HSP 3.0 Host BLE API Documentation

This document describes the available Bluetooth Low Energy (BLE) commands for the MAXREFDES104 Health Sensor Platform 3.0 system. The system's MCU MAX32666 microcontroller with Bluetooth processes all commands. The MAX32674C/MAX32670 functions as the algorithm/sensor hub.

This document supports MCU firmware version 1.2.x and Algo/Sensor Hub firmware 50.3.x.

System Architecture



This document is for the BLE interface between the MAX32666 and the BLE GUI. Not all MAX32674C/MAX32670 Algo/Sensor Hub functions are exposed via the BLE API. The MAX32674C's Algo/Sensor Hub API is a separate document used for integration with a different host MCU.

The user configures the AFE and Algo/Sensor Hub via the BLE interface. When using Algo Hub mode, the host MCU feeds the AFE data to the Algo Hub and reports the results via BLE. In addition, the Algo Hub will request configuration changes when AGC or AEC are enabled, and the host MCU will apply those requests to the AFE. When using Sensor Hub mode, the Sensor Hub reads the data from the AFE directly, processes the data, and the algorithm result/raw values can be read by the host MCU. The AFE control is controlled by the Sensor Hub.

BLE Overview

The BLE device is found by it's advertising name of:

`MAXREFDES104/HSP3.0`

The MAC address contains Maxim Integrated's manufacturer ID (00:18:80) and 24-bit randomly generated portion. The random portion is saved in the MCUs flash memory and is preserved between power cycles. This value is not guaranteed to be unique across all units.

This system requires an MTU size of 220 bytes payload for the notification data characteristics. The Bluetooth host may need to request the size change from the default of 20 bytes.

BLE GATT Service and Characteristics

This document covers the main service consisting of two characteristics. The notify data characteristics is used during data streaming, where the device is actively collecting data and transmitting raw data back to the master. The read/write configuration characteristics is used to setup the system and to perform low level read/write operations.

UUID	Type	Description
6E400000-B5A3-F393-E0A9-E50E24DCCA9E	Service	Service Declaration
6E400001-B5A3-F393-E0A9-E50E24DCCA9E	Characteristic	Notify Data Characteristic
6E400002-B5A3-F393-E0A9-E50E24DCCA9E	Characteristic	Read/Write Configuration Characteristic

Read/Write Configuration Characteristic

The read/write configuration characteristics is used to setup the system and to perform low level read/write operations. There are two command packet formats. The general command packet has the types of write/read, read only, and command only, while the algorithm command packet only has a single format. The Byte Summary section has a list of the commands bytes.

General Command Packet Format

Byte	0	1	2*	3:19*
Description	Target Device	Command	Write/Read	Parameters

* For write/read types, all bytes are used.

* For read only type, byte 2 to 19 are not used.

* For command only type, used by sensor (I2C, AFE, Accelerometer, and Temperature), byte 2 is also a parameter.

The command refers to a function. Write/Read is where 0 = write and 1 = read. After a read command is executed, the result is available in the Read/Write configuration characteristic. The parameters are similar to function parameters.

Read Packet Format

Byte	0	1:19
Description	Message	Data

The definition of the parameters on write and data on read are specified in the command section of this document.

Algorithm Command Format

Byte	0	1	2	3	4:19*
Description	Target Device (Algorithm)	Command	Sub-Command	Read/Write	Parameters

* For reading, bytes 4:19 are not used.

The command and sub-command form a function. Read/Write is where 0 = read and 1 = write (note, this is reversed from the General command packet format). Parameters are similar to function parameters.

Read Packet Format

The read packet is the same format as the command. Bytes 2 and 4:19 contains the read results. For algorithm commands, the target device and message byte is the same value.

Byte	0	1	2	3	4:19
Description	Message	Command	Select	Read/Write	Data

Notify Data Characteristic

UUID	Description
6E400001-B5A3-F393-E0A9-E50E24DCCA9E	Notify Data Characteristic
0x2902	Client Characteristic Configuration Descriptor (CCCD)

This system requires an MTU size of payload size of 220 bytes for the notification data characteristics. The BLE master may need to configure the MTU size. The notify data characteristics contains a single descriptor. The CCCD requires a value of 0x0001 to allow the device to send streaming data packets.

Notify Packet Format

The notification data consists of 220 bytes total. Each packet must be subdivided into 20 byte segments. Each notification will contain 11 subpackets. The subpacket begins with a counter and a notification type byte. The counter increments by each subpacket and rolls over after 255. Below is an example of the 220 byte packet. The Byte Summary section has a list of the notification types.

Byte	0	1	2:19	20	21	22:39	40:219
Description	Counter	Notification Type	Notification Data	Counter + 1	Notification Type	Notification Data	...

This document will only refer to *notification* packets as 20 byte subpackets.

Command and Read Responses

Target Device: MCU

Firmware Version Command

Type: Read Only

Byte	0	1
Description	Target Device	Command
Write	0x00	0x00

Read Response Packet Format

Byte	0	1	2	3	4	5	6	7	8	9	10	11
Description	Message	Data										
Read	0x00	Major	Minor	Year MSB	Year LSB	Month	Day	Patch	0	Algorithm Minor	Algorithm Minor	Algorithm Patch

- Byte 1 - MCU firmware major version number
- Byte 2 - MCU firmware minor version number
- Byte 3:4 - MCU firmware year (16-bit integer)
- Byte 5 - MCU firmware month
    - Value 1 to 12
- Byte 6 - MCU firmware day
    - Value 1 to 31
- Byte 7 - MCU firmware patch version number
- Byte 8 - Zero
    - 0 for released firmware images
- Byte 9 - Algorithm firmware major version number
- Byte 10 - Algorithm firmware minor version number
- Byte 11 - Algorithm firmware patch version number

Enable Sensors Command

Enable sensors starts data streaming via the notification characteristic.

Type: Write/Read

Byte	0	1	2	3 (Write)	4 (Write)	5 (Write)
Description	Target Device	Command	Write/Read	Parameters		
Write	0x00	0x01	0 = Write 1 = Read	Enable	0	0

- Byte 3 - Enable
    - 0 = stop, 1 = start
- Byte 4, 5 - This must be 0x00

Read Response Packet Format

Byte	0	1	2	3
Description	Message	Data		
Read	0x02	Enable	Reserved	Reserved

- Byte 2: Enable
    - 0 = stop, 1 = start

Enable Accelerometer Command

Enable accelerometer data collection when streaming.

Type: Write/Read

Byte	0	1	2	3 (Write)
Description	Target Device	Command	Write/Read	Parameters
Write	0x00	0x05	0 = Write 1 = Read	Enable

- Byte 3: Enable
  - 0 = disabled, 1 = enabled

Read Response Packet Format

Byte	0	1
Description	Message	Data
Read	0x08	Enable

- Byte 2: Enable
  - 0 = disabled, 1 = enabled

Battery Command

Type: Read

Byte	0	1
Description	Target Device	Command
Write	0x00	0x08

Read Response Packet Format

Byte	0	1
Description	Message	Data
Read	0x0D	Status

- Byte 1: Status
  - Bit 7 - Charge state
    - 0 = not charging, 1 = charging
  - Bit 6:0 - Battery charge percentage
    - Display value range is 0 to 100. If value is outside of this range cap the value to the display range.

Status LED Command

Status LED disable/enable command. The status LED can be disabled when collecting data at night or when the human subject is sleeping.

Type: Write/Read

Byte	0	1	2	3 (Write)
Description	Target Device	Command	Write/Read	Parameters
Write	0x00	0x20	0 = Write 1 = Read	Enable

- Byte 3: Enable
  - 0 = disabled, 1 = enable (default)

Read Response Packet Format

Byte	0	1
Description	Message	Data
Read	0x40	Enable

- Byte 2: Enable
  - 0 = disable, 1 = enable

Target Device: Sensor (AFE, Accelerometer, Temperature)

Read Register Command

Read register commands reads a single register.

Type: Command

Byte	0	1	2	3
Description	Target Device	Command	Parameters	
Write		0x00	Register Address	0x01

- Byte 0 - Target device
  - 0x03 - AFE
  - 0x04 - Accelerometer
  - 0x28 - Temperature
- Byte 2 - Register address to read
- Byte 3 - Must be 0x01

Read Response Packet Format

Byte	0	1	2	3	4
Description	Message	Data			
Read	0x04	0x00	0x00	0x00	Register value

- Byte 1, 2, 3 - 0x00
- Byte 4 - Register read result

Read-Modify-Write Register Command

Read-modify-write register command writes a single bit field of the register (or the whole register)

Type: Command

Byte	0	1	2	3	4	5
Description	Target Device	Command	Parameters			
Write		0x01	Register Address	Stop Bit	Start Bit	Write Value

- Byte 0 - Target device
  - 0x03 - AFE
  - 0x04 - Accelerometer
  - 0x28 - Temperature
- Byte 2 - Register address
  - Register address to write
- Byte 3 - Stop bit
  - Stop bit must be larger or equal to the start bit. Use stop = 7 and start = 0 to write the whole register.
  - Value: 0 to 7
- Byte 4 - Start bit
  - Stop bit must be larger or equal to the start bit. Use stop = 7 and start = 0 to write the whole register.
  - Value: 0 to 7
- Byte 5 - Write value
  - Bit field write value

No read response for this command.

Read Register Block Command

Register block read command reads a group of registers with the given starting address and a specified count. Autoincrementing addressing is used to perform the block read. This command is not recommended in Sensor Hub mode.

Type: Command

Byte	0	1	2	3
Description	Target Device	Command	Parameters	
Write		0x02	Register Address	Count

- Byte 0 - Target device
  - 0x03 - AFE
  - 0x04 - Accelerometer
  - 0x28 - Temperature
- Byte 2 - Register address
  - Start of register address of read
- Byte 3 - Number of registers to read
  - Value: 1 to 17

Read Response Packet Format

Byte	0	1	2	3..19
Description	Message	Data		
Read	0x12	0	0	Register Values

- Byte 1, 2 - 0x00
- Byte 3 - Register block read for Register Address
- Byte 4:19 - Register block read result (auto incrementing addressing)

Target Device: Algorithm

Algorithm Mode Command

Type: Algorithm

Byte	0	1	2	3	4
Description	Target Device	Command	Sub-Command	Read/Write	Parameters
Write	0x27	0x01	0xFF	0 = Read 1 = Write	Algorithm Mode

- Byte 2 - 0xFF
- Byte 4 - Algorithm mode
  - 0 - Continuous HR and continuous SpO2
  - 1 - Continuous HR and one-shot SpO2
  - 2 - Continuous HR
  - 3 - Reserved
  - 4 - Reserved
  - 5 - SpO2 calibration (R value output only)

Read Response Packet Format

Byte	0	1	2	3	4
Description	Target Device	Command	Sub-Command	Read	Data
Write	0x27	0x01	0xFF	0	Algorithm Mode

AFE Control Command

Type: Algorithm

Byte	0	1	2	3	4
Description	Target Device	Command	Sub-Command	Read/Write	Parameters
Write	0x27	0x02	0xFF	0 = Read 1 = Write	AFE Control

AEC (automatic exposure control) mode is dynamically adjust the target photodiode current level based upon signal quality and to adjust the LED current to meet the target. AGC (automatic gain control) mode is to adjust the LED current to result in a fixed current level detected at the photodiodes.

- Byte 2 - 0xFF
- Byte 4 - AFE control
  - 0 - None
  - 1 - AEC (automatic exposure control)
  - 2 - AGC (automatic gain control)

Read Response Packet Format

Byte	0	1	2	3	4
Description	Target Device	Command	Sub-Command	Read	Data
Write	0x27	0x02	0xFF	0	AFE Control

AEC Integration Time Command

Type: Algorithm

Byte	0	1	2	3	4
Description	Target Device	Command	Sub-Command	Read/Write	Parameters
Write	0x27	0x03	Integration Time Setting	0 = Read 1 = Write	Integration Time Value

This limits the AEC's configuration of the heart rate measurement's integration time. The integration time is an ADC parameter for the duration of the sample (and related to the duration that the LED is turned on). See the AFE's datasheet for integration time details.

- Byte 2 - Integration time setting
    - 0 - Initial integration time
    - 1 - Minimum integration time
    - 2 - Maximum integration time
- Byte 4 - Integration time value
    - 0 - 14.8us
    - 1 - 29.4us
    - 2 - 58.7us
    - 3 - 117.3us (default)

Read Response Packet Format

Byte	0	1	2	3	4
Description	Target Device	Command	Sub-Command	Read	Data
Write	0x27	0x03	Integration Time Setting	0	Integration Time Value

AEC Sampling Framerate and Averaging Command

Type: Algorithm

Byte	0	1	2	3	4
Description	Target Device	Command	Sub-Command	Read/Write	Parameters
Write	0x27	0x03	Framerate Average Setting	0 = Read 1 = Write	Framerate Average Value

This limits the AEC's configuration of the heart rates framerate and (burst) averaging. Burst averaging captures multiple samples within 1 framerate. See the AFE's datasheet for framerate and (burst) averaging details.

- Byte 2 - Framerate average setting
    - 3 - Initial sampling framerate and (burst) averaging
    - 4 - Minimum sampling framerate and (burst) averaging
    - 5 - Maximum sampling framerate and (burst) averaging
- Byte 4 - Framerate average value
    - 0 - 25fps with 1 average
    - 1 - 50fps with 2 averages
    - 2 - 100fps with 4 averages (default)
    - 3 - 200fps with 8 averages
    - 4 - 400fps with 16 averages

Read Response Packet Format

Byte	0	1	2	3	4
Description	Target Device	Command	Sub-Command	Read	Data
Write	0x27	0x03	Framerate Average Setting	0	Framerate Average Value

AEC Photodiode Current Command

Type: Algorithm

Byte	0	1	2	3	4	5
Description	Target Device	Command	Sub-Command	Read/Write	Parameters	
Write	0x27	0x03	PD Current Setting	0 = Read 1 = Write	0xFF	PD Current Value

This configures the AEC's photodiode (PD) current. The conversion is ADC counts / 2^19 * Full-scale range, where the full-scale range is set to 32uA. The AEC PD current is adjusted by the AEC depending upon the signal condition. The minimum PD current is the lowest level which the AEC is permitted to use. The initial PD current is used by the AEC at start of MCU sensors enable.

- Byte 2 - PD current setting
  - 6 - Minimum PD current
  - 7 - Initial PD current
- Byte 4 - 0xFF
- Byte 5 - PD current value (8-bit integer)
  - PD current in uA. Target initial PD current should be equal or greater than the minimum.
  - Value between 4 to 32.

Read Response Packet Format

Byte	0	1	2	3	4	5
Description	Target Device	Command	Sub-Command	Read	Data	
Write	0x27	0x03	PD Current Setting	0	0xFF	PD Current Value

AEC Target Photodiode Current Period Command

Type: Algorithm

Byte	0	1	2	3	4	5
Description	Target Device	Command	Sub-Command	Read/Write	Parameters	
Write	0x27	0x03	0x08	0 = Read 1 = Write	0xFF	Period Value

This configures the AEC's photodiode target PD current update period.

- Byte 2 - Period setting
  - 8 - Target PD current period
- Byte 4 - 0xFF
- Byte 5 - Period value (8-bit integer)
  - Period is in units of 100s. The code of 1 = 100s and 18 = 1800s.

Read Response Packet Format

Byte	0	1	2	3	4	5
Description	Target Device	Command	Sub-Command	Read	Data	
Write	0x27	0x03	0x08	0	0xFF	Period Value

AEC Motion Detection Threshold Command

Type: Algorithm

Byte	0	1	2	3	4	5
Description	Target Device	Command	Sub-Command	Read/Write	Parameters	
Write	0x27	0x03	0x09	0 = Read 1 = Write	0xFF	Motion Threshold Value

This configures the threshold for AEC high motion operation.

- Byte 2 - Motion threshold setting
  - 9 - Motion threshold
- Byte 4 - 0xFF
- Byte 5 - Motion threshold (8-bit integer)
  - The motion threshold is in units of 0.01*g*. The code of 1 = 0.01*g* and 0x64 = 1.00*g*.
  - Value between 0.01*g* to 1.00*g*.

Read Response Packet Format

Byte	0	1	2	3	4	5
Description	Target Device	Command	Sub-Command	Read	Data	
Write	0x27	0x03	0x09	0	0xFF	Motion Threshold Value

AEC/AGC DAC Offset Command

Type: Algorithm

Byte	0	1	2	3	4	5	6
Description	Target Device	Command	Sub-Command	Read/Write	Parameters		
Write	0x27	0x03	0x0A	0 = Read 1 = Write	Measurement Channel	PPG1 DAC Offset	PPG2 DAC Offset

This configures AEC maximum DAC Offset for a measurement. In AGC mode, this sets the initial and maximum DAC offset for a measurement. See the AFE's datasheet for more details.

- Byte 2 - DAC offset setting
  - 10 - DAC offset
- Byte 4 - Measurement channel
  - 0 to 8 - Measurement 1 to 9
- Byte 5 and 6 - PPG DAC offset
  - 0 - 0uA
  - 1 - 8uA
  - 2 - 16uA
  - 3 - 24uA

Read Response Packet Format

Byte	0	1	2	3	4	5	6
Description	Target Device	Command	Sub-Command	Read	Data		
Write	0x27	0x03	0x0A	0	Measurement Channel	PPG1 DAC Offset	PPG2 DAC Offset

AGC Heart Rate Target Photodiode Current Command

Type: Algorithm

Byte	0	1	2	3	4	5
Description	Target Device	Command	Sub-Command	Read/Write	Parameters	
Write	0x27	0x04	0x0B	0 = Read 1 = Write	0xFF	Target PD Current Value

This configures AGC heart rate's target photodiode current. The AGC adjusts the LED current levels. The target is ADC counts / 2^19 * Full-scale range, where the full-scale range is set to 32uA.

- Byte 2 - Target PD current Setting
  - 11 - Target PD current
- Byte 4 - 0xFF
- Byte 5 - Target PD current value
  - The PD current value is in units of uA.
  - Value is between 4uA to 32uA.

Read Response Packet Format

Byte	0	1	2	3	4	5
Description	Target Device	Command	Sub-Command	Read	Data	
Write	0x27	0x04	0x0B	0	0xFF	Target PD Current Value

SpO2 Averaging Command

Type: Algorithm

Byte	0	1	2	3	4
Description	Target Device	Command	Sub-Command	Read/Write	Parameters

Write	0x27	0x07	Average Setting	0 = Read 1 = Write	Average Value

This sets the SpO2 red and IR LED's burst averaging setting. This applies when HRM is in AEC or AGC modes.

- Byte 2 - Average setting
  - 0 - Initial (burst) averaging
  - 1 - Minimal (burst) averaging
  - 2 - Maximum (burst) averaging
- Byte 4 - Average (burst) value
  - 0 - 1 average
  - 1 - 2 averages
  - 2 - 4 averages (default - initial/minimum)
  - 3 - 8 averages
  - 4 - 16 averages (default - maximum)

Read Response Packet Format

Byte	**0**	**1**	**2**	**3**	**4**
Description	Target Device	Command	Sub-Command	Read	Data
Write	0x27	0x07	Average Setting	0	Average Value

SCD Enable Command

Type: Algorithm

Byte	**0**	**1**	**2**	**3**	**4**
Description	Target Device	Command	Sub-Command	Read/Write	Parameters
Write	0x27	0x06	0x00	0 = Read 1 = Write	Enable

This is the enable for skin contact detect (SCD).

- Byte 2 - SCD Enable
  - 0 - SCD enable
- Byte 4 - Enable
  - 0 - Disable, 1 - Enable

Read Response Packet Format

Byte	**0**	**1**	**2**	**3**	**4**
Description	Target Device	Command	Sub-Command	Read	Data
Write	0x27	0x06	0x00	0	Enable

Operation Mode Command

Type: Algorithm

Byte	**0**	**1**	**2**	**3**	**4**
Description	Target Device	Command	Sub-Command	Read/Write	Parameters
Write	0x27	0xFE	0xFF	0 = Read 1 = Write	Mode Select

This is the operation mode command that configures the MCU's operation for raw or algo hub mode.

- Byte 2 - 0xFF
- Byte 4 - Mode Select
  - 0 - Raw Mode (No algorithm packets)
  - 1 - Algo Hub Mode
  - 2 - Sensor Hub Mode

Read Response Packet Format

Byte	**0**	**1**	**2**	**3**	**4**
Description	Target Device	Command	Sub-Command	Read	Data

Write	0x27	0xFE	0xFF	0	Enable

Notification Packet Format

Periodic Data

The periodic notification byte is 0x03.

Byte	0	1	2	3:4	5:7	8:9	10	11	12:19
Description	Counter	Notify Byte (0x03)	Battery	Reserved	RTC tick	Temperature	AC Lead Off	Status 6	Reserved

- Byte 1 - Notification Byte
  - Periodic Data (0x03)
- Byte 2 - Battery
  - Bit 7 - Charge state
    - 0 = not charging, 1 = charging
  - Bit 6:0 - Battery charge percentage
    - Display value range is 0 to 100. If value is outside of this range cap the value to the display range.
- Byte 5:7 - RTC ticks
  - Real time clock register count
- Byte 8:9 - Temperature
  - 16-bit value where 1 LSB = 0.005°C. Temperature Count = byte[8] << 8 | byte[9]. See the temperature sensor datasheet.
- Byte 10 - AC Lead Off (Future Feature)
  - Firmware cached AC lead off state
  - 0 = normal, 1 = AC lead off detected
- Byte 11 - AFE Status 6 Register (Future Feature)
  - Contents of register containing DC lead off. See the AFE's datasheet.

ECG Data

The ECG notification (0x0B) contains the ECG FIFO data (and accelerometer). The ECG data is 3 bytes and consists of a 5-bit tag, 1-bit flag, and 18-bits for ADC counts. The ADC counts is a two's complement value. See the AFE datasheet's FIFO description for more details. The ECG data is

ecg_sA (24 bit value) = (byte[n] << 16 | byte[n+1] << 8 | byte[n+2])

where:

- A is the sample number

The accelerometer data is provided with the ECG data only if no PPG measurements are enabled. See the PPG Data section for the accelerometer data format.

ECG

6 samples per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x0B)	ecg_s1	ecg_s2	ecg_s3	ecg_s4	ecg_s5	ecg_s6

ECG and Accelerometer (when PPG Disabled)

2 samples per notification set

Byte	0	1	2:4	5:7	8:9	10:11	12:13	14:15	16:17	18:19
Description	Counter	Notify Byte (0x0B)	ecg_s1	ecg_s2	accel_s1_x	accel_s1_y	accel_s1_z	accel_s2_x	accel_s2_y	accel_s2_z

ECG AC Lead Off IQ Data

ECG AC lead off I and Q notification (0x0E) consist of the AC lead off measurement result. Each 3-byte value consists of a 12-bit tag and 12-bit ADC counts component. The tag labels the data as I-channel or Q-channel. The ADC counts is in two's complement format. See the AFE datasheet's FIFO description for more details.

6 points of data per set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x0E)	iq_s1	iq_s2	iq_s3	iq_s4	iq_s5	iq_s6

PPG Data

The PPG data notification (0x00, 0x01, 0x02, and 0x0A) is used when any PPG measurement is enabled. A notification set consists of a number of PPG frames and accelerometer samples. The notification packet data consists of each enabled measurement's PPG1 and PPG2 data, followed by the accelerometer samples. Accelerometer data is padded after the PPG data. (For the case of single PPG, accelerometer, 5 measurements, there are 3 zero-bytes padded in between PPG and accelerometer data.)

The PPG data is 3 bytes and consists of a 4-bit tag and 20-bit ADC counts component. The tag provides measurement information and any overflow conditions. The ADCs counts is a two's complement value. See the AFE datasheet's FIFO description for more details. The PPG data is

opt_sA_mB_ppgC (24 bits) = (byte[n] << 16 | byte[n+1] << 8 | byte[n+2])

where:

- A is the frame (sample) number
- B is the indexed timeslot within the frame (corresponding to the sequence of enabled measurements)
- C is 1 for PPG1 and 2 for PPG2.

The accelerometer is a two's complement value and has been processed where 1 LSB is 1 milli-*g*. The data is not tagged, the full 6-bit value is

accel_sA_D = byte[n] << 8 | byte[n+1]

where

- A is the frame number corresponding with the PPG data
- D is the x-,y-, or z-axis.

Single PPG and Accelerometer

1 Measurement, 1 PPG, and Accelerometer

2 frames per notification set

Byte	**0**	**1**	**2:4**	**5:7**	**8:9**	**10:11**	**12:13**	**14:15**	**16:17**	**18:19**
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s2_m1_ppg1	acc_s1_x	acc_s1_y	acc_s1_z	acc_s2_x	acc_s2_y	acc_s2_z

2 Measurement, 1 PPG, and Accelerometer

3 frames per notification set

Byte	**0**	**1**	**2:4**	**5:7**	**8:10**	**11:13**	**14:16**	**17:19**
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m2_ppg1	opt_s2_m1_ppg1	opt_s2_m2_ppg1	opt_s3_m1_ppg1	opt_s3_m2_ppg1

Byte	**0**	**1**	**2:3**	**4:5**	**6:7**	**8:9**	**10:11**	**12:13**	**14:15**	**16:17**	**18:19**
Description	Counter	Notify Byte (0x01)	acc_s1_x	acc_s1_y	acc_s1_z	acc_s2_x	acc_s2_y	acc_s2_z	acc_s3_x	acc_s3_y	acc_s3_z

3 Measurement, 1 PPG, and Accelerometer

2 frames per notification set

Byte	**0**	**1**	**2:4**	**5:7**	**8:10**	**11:13**	**14:16**	**17:19**
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m2_ppg1	opt_s1_m3_ppg1	opt_s2_m1_ppg1	opt_s2_m2_ppg1	opt_s2_m3_ppg1

Byte	**0**	**1**	**2:3**	**4:5**	**6:7**	**8:9**	**10:11**	**12:13**	**14:19**
Description	Counter	Notify Byte (0x01)	acc_s1_x	acc_s1_y	acc_s1_z	acc_s2_x	acc_s2_y	acc_s2_z	0

4 Measurement, 1 PPG, and Accelerometer

1 frames per notification set

Byte	**0**	**1**	**2:4**	**5:7**	**8:10**	**11:13**	**14:15**	**16:17**	**18:19**
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m2_ppg1	opt_s1_m3_ppg1	opt_s1_m4_ppg1	acc_s1_x	acc_s1_y	acc_s1_z

5 Measurement, 1 PPG, and Accelerometer

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m2_ppg1	opt_s1_m3_ppg1	opt_s1_m4_ppg1	opt_s1_m5_ppg1	0

Byte	0	1	2:3	4:5	6:7	8:19
Description	Counter	Notify Byte (0x01)	acc_s1_x	acc_s1_y	acc_s1_z	0

6 Measurement, 1 PPG, and Accelerometer

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m2_ppg1	opt_s1_m3_ppg1	opt_s1_m4_ppg1	opt_s1_m5_ppg1	opt_s1_m6_ppg1

Byte	0	1	2:3	4:5	6:7	8:19
Description	Counter	Notify Byte (0x01)	acc_s1_x	acc_s1_y	acc_s1_z	0

7 Measurement, 1 PPG, and Accelerometer

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m2_ppg1	opt_s1_m3_ppg1	opt_s1_m4_ppg1	opt_s1_m5_ppg1	opt_s1_m6_ppg1

Byte	0	1	2:4	5:6	7:8	9:10	11:19
Description	Counter	Notify Byte (0x01)	opt_s1_m7_ppg1	acc_s1_x	acc_s1_y	acc_s1_z	0

8 Measurement, 1 PPG, and Accelerometer

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m2_ppg1	opt_s1_m3_ppg1	opt_s1_m4_ppg1	opt_s1_m5_ppg1	opt_s1_m6_ppg1

Byte	0	1	2:4	5:7	8:9	10:11	12:13	14:19
Description	Counter	Notify Byte (0x01)	opt_s1_m7_ppg1	opt_s1_m8_ppg1	acc_s1_x	acc_s1_y	acc_s1_z	0

9 Measurement, 1 PPG, and Accelerometer

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m2_ppg1	opt_s1_m3_ppg1	opt_s1_m4_ppg1	opt_s1_m5_ppg1	opt_s1_m6_ppg1

Byte	0	1	2:4	5:7	8:10	11:12	13:14	15:16	17:19
Description	Counter	Notify Byte (0x01)	opt_s1_m7_ppg1	opt_s1_m8_ppg1	opt_s1_m9_ppg1	acc_s1_x	acc_s1_y	acc_s1_z	0

Dual PPG and Accelerometer

1 Measurement, 2 PPG, and Accelerometer

3 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m1_ppg2	opt_s2_m1_ppg1	opt_s2_m1_ppg2	opt_s3_m1_ppg1	opt_s3_m1_ppg2

Byte	0	1	2:3	4:5	6:7	8:9	10:11	12:13	14:15	16:17	18:19
Description	Counter	Notify Byte (0x01)	acc_s1_x	acc_s1_y	acc_s1_z	acc_s2_x	acc_s2_y	acc_s2_z	acc_s3_x	acc_s3_y	acc_s3_z

2 Measurement, 2 PPG, and Accelerometer

2 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m1_ppg2	opt_s1_m2_ppg1	opt_s1_m2_ppg2	opt_s2_m1_ppg1	opt_s2_m1_ppg2

Byte	0	1	2:4	5:7	8:9	10:11	12:13	14:15	16:17	18:19
Description	Counter	Notify Byte (0x01)	opt_s2_m2_ppg1	opt_s2_m2_ppg2	acc_s1_x	acc_s1_y	acc_s1_z	acc_s2_x	acc_s2_y	acc_s2_z

3 Measurement, 2 PPG, and Accelerometer

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m1_ppg2	opt_s1_m2_ppg1	opt_s1_m2_ppg2	opt_s1_m3_ppg1	opt_s1_m3_ppg2

Byte	0	1	2:3	4:5	6:7	8:19
Description	Counter	Notify Byte (0x01)	acc_s1_x	acc_s1_y	acc_s1_z	0

4 Measurement, 2 PPG, and Accelerometer

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m1_ppg2	opt_s1_m2_ppg1	opt_s1_m2_ppg2	opt_s1_m3_ppg1	opt_s1_m3_ppg2

Byte	0	1	2:4	5:7	8:9	10:11	12:13	14:19
Description	Counter	Notify Byte (0x01)	opt_s1_m4_ppg1	opt_s1_m4_ppg2	acc_s1_x	acc_s1_y	acc_s1_z	0

5 Measurement, 2 PPG, and Accelerometer

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m1_ppg2	opt_s1_m2_ppg1	opt_s1_m2_ppg2	opt_s1_m3_ppg1	opt_s1_m3_ppg2

Byte	0	1	2:4	5:7	8:10	11:13	14:15	16:17	18:19
Description	Counter	Notify Byte (0x01)	opt_s1_m4_ppg1	opt_s1_m4_ppg2	opt_s1_m5_ppg1	opt_s1_m5_ppg2	acc_s1_x	acc_s1_y	acc_s1_z

6 Measurement, 2 PPG, and Accelerometer

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m1_ppg2	opt_s1_m2_ppg1	opt_s1_m2_ppg2	opt_s1_m3_ppg1	opt_s1_m3_ppg2

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x01)	opt_s1_m4_ppg1	opt_s1_m4_ppg2	opt_s1_m5_ppg1	opt_s1_m5_ppg2	opt_s1_m6_ppg1	opt_s1_m6_ppg2

Byte	0	1	2:3	4:5	6:7	8:19
Description	Counter	Notify Byte (0x02)	acc_s1_x	acc_s1_y	acc_s1_z	0

7 Measurement, 2 PPG, and Accelerometer

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m1_ppg2	opt_s1_m2_ppg1	opt_s1_m2_ppg2	opt_s1_m3_ppg1	opt_s1_m3_ppg2

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x01)	opt_s1_m4_ppg1	opt_s1_m4_ppg2	opt_s1_m5_ppg1	opt_s1_m5_ppg2	opt_s1_m6_ppg1	opt_s1_m6_ppg2

Byte	0	1	2:4	5:7	8:9	10:11	12:13	14:19
Description	Counter	Notify Byte (0x02)	opt_s1_m7_ppg1	opt_s1_m7_ppg2	acc_s1_x	acc_s1_y	acc_s1_z	0

8 Measurement, 2 PPG, and Accelerometer

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m1_ppg2	opt_s1_m2_ppg1	opt_s1_m2_ppg2	opt_s1_m3_ppg1	opt_s1_m3_ppg2

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x01)	opt_s1_m4_ppg1	opt_s1_m4_ppg2	opt_s1_m5_ppg1	opt_s1_m5_ppg2	opt_s1_m6_ppg1	opt_s1_m6_ppg2

Byte	0	1	2:4	5:7	8:10	11:13	14:15	16:17	18:19
Description	Counter	Notify Byte (0x02)	opt_s1_m7_ppg1	opt_s1_m7_ppg2	opt_s1_m8_ppg1	opt_s1_m8_ppg2	acc_s1_x	acc_s1_y	acc_s1_z

9 Measurement, 2 PPG, and Accelerometer

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m1_ppg2	opt_s1_m2_ppg1	opt_s1_m2_ppg2	opt_s1_m3_ppg1	opt_s1_m3_ppg2

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x01)	opt_s1_m4_ppg1	opt_s1_m4_ppg2	opt_s1_m5_ppg1	opt_s1_m5_ppg2	opt_s1_m6_ppg1	opt_s1_m6_ppg2

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x02)	opt_s1_m7_ppg1	opt_s1_m7_ppg2	opt_s1_m8_ppg1	opt_s1_m8_ppg2	opt_s1_m9_ppg1	opt_s1_m9_ppg2

Byte	0	1	2:3	4:5	6:7	8:19
Description	Counter	Notify Byte (0x0A)	acc_s1_x	acc_s1_y	acc_s1_z	0

Single PPG

1 Measurement, 1 PPG

6 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s2_m1_ppg1	opt_s3_m1_ppg1	opt_s4_m1_ppg1	opt_s5_m1_ppg1	opt_s6_m1_ppg1

2 Measurement, 1 PPG

3 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m2_ppg1	opt_s2_m1_ppg1	opt_s2_m2_ppg1	opt_s3_m1_ppg1	opt_s3_m2_ppg1

3 Measurement, 1 PPG

2 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m2_ppg1	opt_s1_m3_ppg1	opt_s2_m1_ppg1	opt_s2_m2_ppg1	opt_s2_m3_ppg1

4 Measurement, 1 PPG

3 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m2_ppg1	opt_s1_m3_ppg1	opt_s1_m4_ppg1	opt_s2_m1_ppg1	opt_s2_m2_ppg1

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x01)	opt_s2_m3_ppg1	opt_s2_m4_ppg1	opt_s3_m1_ppg1	opt_s3_m2_ppg1	opt_s3_m3_ppg1	opt_s3_m4_ppg1

5 Measurement, 1 PPG

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m2_ppg1	opt_s1_m3_ppg1	opt_s1_m4_ppg1	opt_s1_m5_ppg1	0

6 Measurement, 1 PPG

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m2_ppg1	opt_s1_m3_ppg1	opt_s1_m4_ppg1	opt_s1_m5_ppg1	opt_s1_m6_ppg1

7 Measurement, 1 PPG

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m2_ppg1	opt_s1_m3_ppg1	opt_s1_m4_ppg1	opt_s1_m5_ppg1	opt_s1_m6_ppg1

Byte	0	1	2:4	5:19
Description	Counter	Notify Byte (0x01)	opt_s1_m7_ppg1	0

8 Measurement, 1 PPG

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m2_ppg1	opt_s1_m3_ppg1	opt_s1_m4_ppg1	opt_s1_m5_ppg1	opt_s1_m6_ppg1

Byte	0	1	2:4	5:7	8:19
Description	Counter	Notify Byte (0x01)	opt_s1_m7_ppg1	opt_s1_m8_ppg1	0

9 Measurement, 1 PPG

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m2_ppg1	opt_s1_m3_ppg1	opt_s1_m4_ppg1	opt_s1_m5_ppg1	opt_s1_m6_ppg1

Byte	0	1	2:4	5:7	8:10	11:19
Description	Counter	Notify Byte (0x01)	opt_s1_m7_ppg1	opt_s1_m8_ppg1	opt_s1_m9_ppg1	0

Dual PPG

1 Measurement, 2 PPG

3 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19

Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m1_ppg2	opt_s2_m1_ppg1	opt_s2_m1_ppg2	opt_s3_m1_ppg1	opt_s3_m1_ppg2

2 Measurement, 2 PPG

3 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m1_ppg2	opt_s1_m2_ppg1	opt_s1_m2_ppg2	opt_s2_m1_ppg1	opt_s2_m1_ppg2

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x01)	opt_s2_m2_ppg1	opt_s2_m2_ppg2	opt_s3_m1_ppg1	opt_s3_m1_ppg2	opt_s3_m2_ppg1	opt_s3_m2_ppg2

3 Measurement, 2 PPG

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m1_ppg2	opt_s1_m2_ppg1	opt_s1_m2_ppg2	opt_s1_m3_ppg1	opt_s1_m3_ppg2

4 Measurement, 2 PPG

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m1_ppg2	opt_s1_m2_ppg1	opt_s1_m2_ppg2	opt_s1_m3_ppg1	opt_s1_m3_ppg2

Byte	0	1	2:4	5:7	8:19
Description	Counter	Notify Byte (0x01)	opt_s1_m4_ppg1	opt_s1_m4_ppg2	0

5 Measurement, 2 PPG

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m1_ppg2	opt_s1_m2_ppg1	opt_s1_m2_ppg2	opt_s1_m3_ppg1	opt_s1_m3_ppg2

Byte	0	1	2:4	5:7	8:10	11:13	14:19
Description	Counter	Notify Byte (0x01)	opt_s1_m4_ppg1	opt_s1_m4_ppg2	opt_s1_m5_ppg1	opt_s1_m5_ppg2	0

6 Measurement, 2 PPG

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m1_ppg2	opt_s1_m2_ppg1	opt_s1_m2_ppg2	opt_s1_m3_ppg1	opt_s1_m3_ppg2

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x01)	opt_s1_m4_ppg1	opt_s1_m4_ppg2	opt_s1_m5_ppg1	opt_s1_m5_ppg2	opt_s1_m6_ppg1	opt_s1_m6_ppg2

7 Measurement, 2 PPG

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m1_ppg2	opt_s1_m2_ppg1	opt_s1_m2_ppg2	opt_s1_m3_ppg1	opt_s1_m3_ppg2

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x01)	opt_s1_m4_ppg1	opt_s1_m4_ppg2	opt_s1_m5_ppg1	opt_s1_m5_ppg2	opt_s1_m6_ppg1	opt_s1_m6_ppg2

Byte	0	1	2:4	5:7	8:19

Description	Counter	Notify Byte (0x02)	opt_s1_m7_ppg1	opt_s1_m7_ppg2	0

8 Measurement, 2 PPG

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m1_ppg2	opt_s1_m2_ppg1	opt_s1_m2_ppg2	opt_s1_m3_ppg1	opt_s1_m3_ppg2

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x01)	opt_s1_m4_ppg1	opt_s1_m4_ppg2	opt_s1_m5_ppg1	opt_s1_m5_ppg2	opt_s1_m6_ppg1	opt_s1_m6_ppg2

Byte	0	1	2:4	5:7	8:10	11:13	14:19
Description	Counter	Notify Byte (0x02)	opt_s1_m7_ppg1	opt_s1_m7_ppg2	opt_s1_m8_ppg1	opt_s1_m8_ppg2	0

9 Measurement, 2 PPG

1 frames per notification set

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x00)	opt_s1_m1_ppg1	opt_s1_m1_ppg2	opt_s1_m2_ppg1	opt_s1_m2_ppg2	opt_s1_m3_ppg1	opt_s1_m3_ppg2

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x01)	opt_s1_m4_ppg1	opt_s1_m4_ppg2	opt_s1_m5_ppg1	opt_s1_m5_ppg2	opt_s1_m6_ppg1	opt_s1_m6_ppg2

Byte	0	1	2:4	5:7	8:10	11:13	14:16	17:19
Description	Counter	Notify Byte (0x02)	opt_s1_m7_ppg1	opt_s1_m7_ppg2	opt_s1_m8_ppg1	opt_s1_m8_ppg2	opt_s1_m9_ppg1	opt_s1_m9_ppg2

Algorithm Data

Algorithm data notification (0x10) is only sent if Algo Hub or Sensor Hub modes are enabled. It is not used in raw mode operation.

Byte	0	1	2	3	4	5:6	7
Description	Counter	Notify Byte (0x10)	Algo Mode	HR	HR Confidence	RR	RR Confidence

8	9	10:11	12	13	14	15	16	17:19
SpO2	Reserved	R	SpO2 Complete	Reserved	Activity	SCD State	Flags	Reserved

- Byte 1 - Notify Byte
  - Algorithm Data (0x10)
- Byte 2 - Algorithm Mode
  - See Target Device: Algorithm algorithm mode command
- Byte 3 - Heart Rate (bpm)
- Byte 4 - Heart Rate Confidence (percent)
- Byte 5:6 - R-to-R Interval (ms)
  - R-to-R beat interval in milliseconds
- Byte 7 - R-to-R Interval Confidence (percent)
- Byte 8 - SpO2 (percent)
- Byte 10:11 - R ratio (unitless)
  - R value is used for SpO2 calculation. The data format is 16-bit unsigned.
  - R value = (byte[10] << 8 | byte[11])/1000
- Byte 12 - SpO2 Complete Flag
  - 0 = byte[8] not valid
  - 1 = Value of byte[8] is valid/has been updated
- Byte 14 - Activity
  - 0 - Light
  - 1 - Other
  - 2 - Walking
  - 3 - Running
  - 4 - Biking
- Byte 15 - SCD State
  - 0 - No Decision
  - 1 - Off Skin
  - 2 - On Some
  - 3 - Detected

- Byte 16 - Flags
  - Bit 0 - SpO2 Low Signal Quality (when 1)
  - Bit 1 - SpO2 Excessive Motion (when 1)
  - Bit 2 - SpO2 Low PI (when 1)
  - Bit 3 - SpO2 Unreliable R (when 1)

Stop Complete

The stop complete notification (0xFE) signals that the sensors disable command is completed.

Byte	0	1	2:19
Description	Counter	Notify Byte (0xFE)	0x00

Padding

The padding notification (0xFF) is used to pad the 240 bytes of data for transmission. This notification can be ignored.

Byte	0	1	2:19
Description	Counter	Notify Byte (0xFF)	0x00

File and Flash (Binary) Logging

File logging saves all data locally on the user's system. Flash logging logs the data to the reference design's flash memory. File and flash logging use the same binary file format. The file format contains three sections: header, body, footer. The header format contains register and setup information. The body contains all of the notification packets. The footer contains a stop time stamp. The reference design's software application in the installation folder contains a standalone parser application which processes the binary data and outputs CSV files.

For file logging, the application will generate and write the header, save all notification packets to the file, and generate and write the footer. In flash logging mode, the application generates and write the header via the logging target device. The system will save all notification bytes to flash memory. Upon stopping, the application will generate and write the footer.

Flash logging output file is accessed USB-C. When plugged in, the reference design will appear as a USB mass storage device. After enabling sensors, the MCU will disable BLE and begin logging. The LED will blink with a cyan color. To stop logging, press the 'F' button on the wristband. Logging will stop and the device will turn off. Flash logging has a data rate limit more stringent than BLE streaming. It is not recommended to enable PPG and ECG data collection at the same time to avoid dropped data points.

Header Format

The header packet size is 18 bytes with 7 rows. Hex values with white background are register address for the AFE (MAX86176). Write the contents of the register into those cells. The values with a green cell color have additional description.

Byte	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
H1	0x10	0x11	0x12	0x13	0x14	0x18	0x19	0x1A	0x1C	0x1D	0x1E	0x20	0x21	0x22	0x23	0x24	0x25	0x26
H2	0	0	0xFE	0xFF	0x07	0xAF	0x02	0	0	0	0x1F	WC[3]	WC[2]	WC[1]	WC[0]	ENACC	WC[5]	WC[4]
H3	0x28	0x29	0x2A	0x2B	0x2C	0x2D	0x2E	0	0	0x30	0x31	0x32	0x33	0x34	0x35	0x36	0	0
H4	0x38	0x39	0x3A	0x3B	0x3C	0x3D	0x3E	0	0	0x40	0x41	0x42	0x43	0x44	0x45	0x46	0	0
H5	0x48	0x49	0x4A	0x4B	0x4C	0x4D	0x4E	0	0	0x50	0x51	0x52	0x53	0x54	0x55	0x56	0	0
H6	0x58	0x59	0x5A	0x5B	0x5C	0x5D	0x5E	0	EFTR	0x60	0x61	0x62	0x63	0x64	0x65	0x66	ESR[1]	ESR[0]
H7	0x90	0x91	0x92	0x93	0x94	0x95	0x96	0x97	0x98	0x99	0x9A	0x9B	0x9E	0xA8	0xA9	0	0	0

Header 2

Byte 0, 1, 4:10 - Write the value in the cells to the file/flash log.

Byte 11:14, 16:17 - WC. Wall Clock. Write the start time's wall clock epoch time (Unix time) in milliseconds to these cells. The byte order where WC[5] is the MSB and WC[0] is the LSB.

Byte 15 - ENACC. Current Enable Accelerometer Configuration . Write the current enable accelerometer configuration. 0 = Accelerometer is currently disabled, 1 = Accelerometer is currently enabled.

Header 2-5

Byte 7:8, 16:17 - Write zero.

Header 6

Byte 7 - Write zero.

Byte 8 - EFTR. ECG Filter Settings (8-bit). ECG data post processing filter settings. This applies the ECG filter settings for post processing of ECG data. See the reference design's user guide for ECG filter details.

Bit	7:6	4:2	1	0
Name	Notch	Cut Off	Baseline Removal	Adaptive
Description	0 = Off 1 = 50Hz 2 = 60Hz 3 = 50 & 60Hz	0 = Off 1 = 30Hz 2 = 40Hz 3 = 50Hz 4 = 60Hz 5 = 100Hz 6 = 150Hz	0 = Off 1 = On	0 = Off 1 = On

Byte 16:17 - ESR. ECG Sample Rate (16-bit unsigned). Write the current configured ECG sample rate (supported filter rates are 128, 200, 250, 256, 300, 500, 512, 1024sps). Note that the reference design's available ECG sample rates does not match all the available filter rates. Write 0 if ECG is not enabled.

Header 7

Byte 15:17 - Write zero.

Body Format

Notification packets with size of 20 bytes, where byte 0 is the counter, byte 1 is the notification byte, and bytes 2:19 are the data points.

Footer Format

The footer packet size is 18 bytes with a single row.

Byte	0	1	2	3	4	5	6:17
F1	WC[3]	WC[2]	WC[1]	WC[0]	WC[5]	WC[4]	0

Byte 0:5. WC. Wall Clock. Write the stop time's wall clock epoch time (Unix time) in milliseconds to these cells. The byte order where WC[5] is the MSB and WC[0] is the LSB.

Byte 6:17. Write zero.

Applications Information

The Windows PC application can be used to determine the setup configuration parameters required. Those can be mapped to the BLE characteristics commands. The start sequence enables the data streaming and is end by a stop command.

AFE Control Modes

Algo Hub

When using Algo Hub, there are three AFE control modes available: Manual, AEC, AGC. Depending upon the mode, register fields are user controlled or MCU controlled. When user controlled, the register values must be directly written before enabling sensors. If all three modes are used, consider setting all register values each time.

Mode	Framerate/ Averaging	Integration Time	Initial LED Currents	DAC Offset	Other Meas Configurations
Manual	User	User	User	User	User
AEC	MCU	MCU	MCU	MCU	User
AGC	User	User	MCU	User	User

* Meas 1 is used for heart rate. Meas 2 is used for SpO2 IR channel. Meas 3 is used for SpO2 Red channel.

Sensor Hub

For Sensor Hub, the register settings are dynamically adjusted during operation. Initial configurations are set by BLE API commands and depending upon mode will adjust during operation. The exception are initial LED currents, this is set by directly writing to the AFE registers.

Operational Mode Matrix

Not all mode combinations are available, the limitations are noted in the table below.

Mode	BLE/File Log (1)	Flash Log
Raw	Y	Y (2)
Algo Hub	Y	Y (2)
Sensor Hub	Y (2)	N

Notes: 1 = Limited by BLE data rate; 2 = Limited by flash memory writes. Only use 3 channel PPG with accelerometer or ECG only.

Setup

Raw Mode

1. Algorithm: Raw/Algo Mode Command - set to Raw Mode
2. AFE: Setup all device registers - consider using the MAXREFDES104 GUI application's register export feature to setup the AFE's registers values.
3. MCU: Enable Accelerometer Command - enable or disable based upon use

Algo Hub Mode

1. Algorithm: Operation Mode Command - set to Algo Hub Mode
2. Algorithm: AFE Control Command - set to none, AEC, or AGC. If using AEC, configure all AEC commands. If using AGC configure the AGC command.
3. AFE: Setup AFE's device registers (considering using the MAXREFDES104 GUI application's register export feature after configuring it for Algo Mode)
    a. Framerate to 25fps
    b. Enable Meas 1, 2, and 3.
    c. Setup Measurement configuration. Meas 1 for green (HR), Meas 2 (IR), and Meas 3 (Red).
    d. LED currents (if using none for AFE Control)
4. MCU: Enable Accelerometer Command - set to enable (required in Algo Hub mode)

Sensor Hub Mode

1. Algorithm: AFE Control Command - set to none, AEC, or AGC. If using AEC, configure all AEC commands. If using AGC configure the AGC command.
2. AFE: Setup AFE's via host BLE API commands for AEC and AGC. For manual control, setup the LED current by writing to the register directly.
3. MCU: Enable Accelerometer Command - set to enable
4. Algorithm: Operation Mode Command - set to Sensor Hub Hub Mode

Start/Stop Sequence

No logging is with no data value saved. File logging is saving the data values on the local BLE host. Flash logging is saving data on the system's flash memory.

No Logging and File Logging

1. Setup all registers and algorithm configurations
2. File Logging Only - Generate header
    a. File log - write header bytes to file
3. MCU: Enable Sensors Command - start data capture
4. Receive notification packets and log/process the values.
    a. File log - write packets to file. (Flash log will automatically write the files to flash memory.)
5. MCU: Enable Sensors Command - request stop data capture
6. Receive notification stop packet (0xFE) to signal the end. Ignore the remaining padding (0xFF) packets.
7. File Logging Only - Generate footer
    a. File log - write footer bytes to file and close file

Flash Logging

1. Setup all registers and algorithm configurations
2. Generate header
    a. Write header bytes to Log API
3. Log API - Enable flash logging mode
4. MCU: Enable Sensors Command - start data capture
    a. Bluetooth LE will disconnect
    b. LED will blink with cyan color
5. Push 'F' button on wristband to stop
6. Connect USB-C to view retrieve the bin file data results.

Byte Summary

Target Device Byte Summary

Target Device	Byte	Description
MCU	0x00	MAX32666
Log	0x01	External Flash
Reserved	0x02	
AFE	0x03	MAX86176
Accelerometer	0x04	LIS2DS12
Algorithm	0x27	MAX32674C (MAX32670)
Temperature	0x28	MAX30208

MCU Device Command Byte Summary

Command	Byte
Firmware Version	0x00
Enable Sensors	0x01
Enable Accelerometer	0x05
Battery	0x08
Status LED	0x20

General (MCU/Log) Write/Read Byte Summary

Write/Read	Byte
Write	0x00
Read	0x01

Algorithm Read/Write Byte Summary

Read/Write	Byte
Read	0x00
Write	0x01

AFE/Accelerometer/Temperature Command Byte Summary

Command	Byte
Read Register	0x00
Read-Modify-Write Register	0x01
Read Register Block	0x02

Algorithm Command Byte Summary

Command	Byte	Select	Byte
Algorithm Mode	0x01	-	0xFF
AFE Control	0x02	-	0xFF
AEC	0x03	Initial Integration Time	0x00
AEC	0x03	Minimum Integration Time	0x01
AEC	0x03	Maximum Integration Time	0x02

AEC	0x03	Initial Framerate and Averaging	0x03
AEC	0x03	Minimum Framerate and Averaging	0x04
AEC	0x03	Maximum Framerate and Averaging	0x05
AEC	0x03	Minimum Photodiode Current	0x06
AEC	0x03	Initial Photodiode Current	0x07
AEC	0x03	Photodiode Current Period	0x08
AEC	0x03	Motion Detection Threshold	0x09
AEC	0x03	DAC Offset	0x0A
AGC	0x04	Target Photodiode Current	0x0B
SPO2	0x07	Initial Averaging	0x00
SPO2	0x07	Minimum Averaging	0x01
SPO2	0x07	Maximum Averaging	0x02
LED PD	0x05	Heart Rate LED PD Selection	0x00
LED PD	0x05	SpO2 Heart Rate LED PD Selection	0x01
SCD	0x06	SCD Enable	0x00
Raw/Algo Mode	0xFE	Raw/Algo Mode Selection	0xFF

Messages Byte Summary

These are the return message byte after a read command is issue.

Message	Byte
MCU Firmware Version	0x00
MCU Enable Sensors	0x01
Register Value	0x04
MCU Enable Accelerometer	0x08
MCU Read Battery	0x0D
Register Block Read	0x12
MCU Status LED	0x40

Notify Byte Summary

Message	Byte	Description
Sensor0	0x00	Raw PPG/accelerometer sensor data
Sensor1	0x01	Raw PPG/accelerometer sensor data
Sensor2	0x02	Raw PPG/accelerometer sensor data
Periodic	0x03	Status/temperature/RTC data
Sensor3	0x0A	Raw PPG/accelerometer sensor data
ECG	0x0B	Raw ECG data
Timestamp0	0x0C	PPG timing data
Timestamp1	0x0D	PPG timing data
IQ0	0x0E	ECG AC lead off IQ data
IQ1	0x0F	ECG AC lead off IQ data
Algorithm	0x10	HR and SpO2 data
Stop Completed	0xFE	Stopping sensors completed
Padding	0xFF	Padding to fill a packet (ignore these packets)