Made by	30.04.2015	SH	_____
Checked by	_____	__	_____
Accepted by	_____	__	_____

eMotion Faros Bluetooth protocol: Online mode

Table of contents

1 GENERAL INFORMATION

1.1 Bluetooth security

Faros' Bluetooth module uses Secure Simple Pairing. For Bluetooth 2.0 hosts Bluetooth PIN code (passkey) **3448** is required.

1.2 Maximizing measurement time

Longest measurement time can be achieved when the following principals are used.

1) Set sampling frequencies for ECG and accelerometer to as low as possible for the application.
2) Keep the device and receiving unit in close proximity.

2 COMMANDS

2.1 General

Commands are ASCII-strings terminated with Carriage Return (<CR>, 0x0D, '\r'). All parameters must be set before measurement is started.

2.2 Command set

Table 1: Commands and responses when measurement is stopped

Refer to Chapter	Command	Command length	Response	Response length	Description
2.2.1	wbainf\r	7	11104010\r	9	Firmware: v1.1.1.0, hardware: v4.0, protocol: v1.0
2.2.1	wbaind\r	7	20140826\r	9	Firmware build date: 26 August 2014
2.2.2	wbasg0\r	7	no response	0	Set ECG signal resolution to 0.25 µV/count
2.2.2	wbasg1\r	7	no response	0	Set ECG signal resolution to 1.00 µV/count [1)]
2.2.3	wbash0\r	7	no response	0	Set high-pass filter to 1 Hz for ECG signal [1)]
2.2.3	wbash1\r	7	no response	0	Set high-pass filter to 10 Hz for ECG signal
2.2.4	wbafs1\r	7	no response	0	Set ECG sampling frequency to 1000 Hz
2.2.4	wbafs2\r	7	no response	0	Set ECG sampling frequency to 500 Hz
2.2.4	wbafs4\r	7	no response	0	Set ECG sampling frequency to 250 Hz
2.2.4	wbafs8\r	7	no response	0	Set ECG sampling frequency to 125 Hz
2.2.4	wbafst\r	7	no response	0	Set ECG sampling frequency to 100 Hz [1)]
2.2.5	wbaar0\r	7	no response	0	Set accelerometer resolution to 0.25 mg/count
2.2.5	wbaar1\r	7	no response	0	Set accelerometer resolution to 1 mg/count [1)]
2.2.6	wbaas1\r	7	no response	0	Set accelerometer sampling frequency to 100 Hz
2.2.6	wbaas2\r	7	no response	0	Set accelerometer sampling frequency to 50 Hz
2.2.6	wbaas3\r	7	no response	0	Set accelerometer sampling frequency to 40 Hz
2.2.6	wbaas4\r	7	no response	0	Set accelerometer sampling frequency to 25 Hz
2.2.6	wbaast\r	7	no response	0	Set accelerometer sampling frequency to 20 Hz [1)]
2.2.7	wbaom7\r	7	wbav10\r or wbaerr\r	7	Start online measurement using data format v1.0
2.2.7	wbaom8\r	7	wbav10\r or wbaerr\r	7	Start synchronised online measurement using data format v1.0.
2.2.8	wbaom0\r	7	wbaack\r	7	Power off device

2.2.9	wbasds1t10 1t10\r	15	wbaack\r or wbaerr\r	7	Set device settings in a single string
2.2.9	wbagds\r	7	wba1t101t10\r	12	Get device settings in a single string
2.2.10	wbawho\r	7	AATOS-01234\r	12	Get device Bluetooth name
2.2.11	wbaled\r	7	no response	7	Blink device LEDs
2.2.12	wbassc\r	7	wbaack\r	7	Start clock calibration sequence

1) Default settings

2.2.1 Firmware information

Commands ”wbainf\r” and ”wbaind\r” can be used for firmware version information. Device responses with ASCII strings.

2.2.2 Set gain

Default gain is 1.0 µV. This means that 1 count change in raw ADC value is equal to 1.0 µV change in signal.

2.2.3 Set high-pass

Default high-pass is 1 Hz. 10 Hz high-pass can be used if signal shape is not important and motion artefacts are expected.

2.2.4 Sampling frequency, ECG signal

ECG samples are collected with sampling frequency selected by command “wbafs*\r”

2.2.5 Accelerometer resolution

Default accelerometer resolution is 1.0 mg/count. This means that 1 count change in accelerometer value is equal to 1.0 mg change in acceleration. If more accurate acceleration readings are desirable, accelerometer resolution can be set to 0.25 mg/count. This means that 1 count change in accelerometer value is equal to 0.25 mg change in acceleration. Please note that increasing the accelerometer resolution reduces the dynamic range of the accelerometer from ±8g to ±2g.

2.2.6 Sampling frequency, Accelerometer signal

Accelerometer samples are collected with sampling frequency selected by command “wbaas*\r”

2.2.7 Start measurement

“wbaom7\r” starts online measurement with selected configuration of ECG and accelerometer (and other) signals using data packet format v1.0. Device responses “wbav10\r” if command is successfully received. If there is an internal error device responses “wbaerr\r” and measurement doesn’t start. Data is sent data at 200 millisecond intervals.

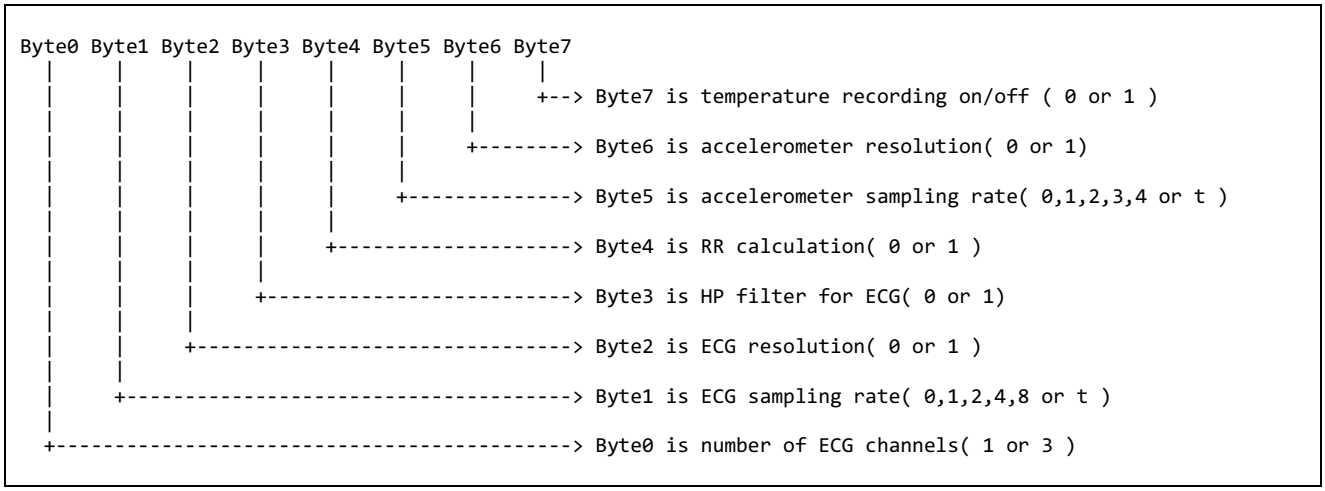
“wbaom8\r” starts synchronised online measurement with selected configuration of ECG and accelerometer (and other) signals using data packet format v1.0. Device responses “wbav10\r” if command is successfully received. If there is an internal error device responses “wbaerr\r” and measurement doesn’t start. Data is sent data at 200 millisecond intervals. Device waits for synchronisation pulse before it starts recording/sending data.

2.2.8 Power off device

Device is powered off when device receives "wbaom0\r" command. Device responses "wbaack\r" if command is successfully received.

2.2.9 Set/get device settings in a single string

Device settings can be set/get using a single string. When “wbagds\r” command is sent device responds with a 8 byte(+ \r) string that contains the current settings. Device settings can be set by sending “wbasds” followed by 8 byte(+ \r) string that contains the new settings . If the new settings are valid the device responds with “wbaack”, if the settings are invalid device responds with “wbaerr”.



- **Byte0:** Number of ECG channels recorded, default 1. Only Faros 360 device supports 3 channel recording.
- **Byte1:** ECG sampling rate.
  0 = ECG not recorded
  1 = **1000** Hz ECG sampling rate.
  2 = **500** Hz ECG sampling rate.
  4 = **250** Hz ECG sampling rate.
  8 = **125** Hz ECG sampling rate.
  t = **100** Hz ECG sampling rate, default setting.
- **Byte2:** ECG resolution.
  0 = ECG signal resolution is **0.25** µV/count.
  1 = ECG signal resolution is **1.00** µV/count, default setting.
- **Byte3:** High-pass filter cut of frequency for ECG.
  0 = Set high-pass filter to **1** Hz for ECG signal, default setting.
  1 = Set high-pass filter to **10** Hz for ECG signal.
- **Byte4:** RR interval calculation on/off.
  0 = RR interval calculation/recording is off.
  1 = RR interval is calculated and recorded, default setting.
- **Byte5:** Accelerometer sampling rate.
  0 = Accelerometer data not recorded
  1 = **100** Hz accelerometer sampling rate.
  2 = **50** Hz accelerometer sampling rate.
  3 = **40** Hz accelerometer sampling rate.

4 = **25** Hz accelerometer sampling rate.
t = **20** Hz accelerometer sampling rate, default setting.

- **Byte6:** Accelerometer resolution.
  0 = Accelerometer signal resolution is **0.25** mg/count.
  1 = Accelerometer signal resolution is **1.00** mg/count, default setting.
- **Byte7:** Temperature recording on/off.
  0 = Temperature is not recorded, default setting.
  1 = Temperature is recorded. Only Faros 360 device supports temperature recording.

2.2.10 Get device name

Device name can be acquired by sending command “wbawho\r”. Device responds with its Bluetooth name.

2.2.11 Blink device LEDs

When device receives "wbaled\r" command it blinks its LEDs momentarily.

2.2.12 Start clock calibration sequence

Clock calibration is used in synchronised measurement mode. Device responds “wba_ok\r” if clock calibration was successful and “wba_er\r” if the clock calibration was unsuccessful.

3 DATA PROTOCOL V1.0 FOR ECG, ACCELEROMETER, HRV AND TEMPERATURE DATA

3.1 Data format 1.0

Data packet size varies between **28** and **1352** bytes depending on the selected configuration. Each packet contains data from **200** ms period. Examples of different configurations and their packet sizes are shown below.

Table 2: Example configurations and their packet sizes in 1.0 protocol

ECG samplerate	nes	nec	Accelerometer samplerate	nas	nrs	nts	npb	Data packet size (bytes)
1000	200	3	100	20	1	1	2	1352
1000	200	1	100	20	1	1	2	552
250	50	1	25	5	0	0	0	156
250	50	3	0	0	0	1	0	328
125	25	1	25	5	0	0	2	108
100	20	1	100	20	0	0	2	188
100	20	1	20	4	1	0	0	92
0	0	-	100	20	1	0	0	148
0	0	-	50	10	1	0	0	88
0	0	-	0	0	1	0	0	28

nes = Number of ECG Samples/packet/channel(**0, 20, 25, 50, 100** or **200**)
nec = Number of ECG Channels(**1** or **3**)
nas = Number of Accelerometer Samples/packet/axis(**0, 2, 4, 5, 8, 10** or **20**)
nrs = Number of RR interval Samples/packet(**0** or **1**)
nts = Number of Temperature sensor Samples/packet(**0** or **1**)
npb = Number of Padding Bytes to make frame length divisible by 4(**0** or **2**)

Data packet size in bytes = 26 + (nes * nec * 2) + (nas * 6) + (nrs * 2) + (nts * 2) + npb

An example of a data packet is shown below. Bytes marked with 0xNN can have any value (from 0x00 to 0xFF).

Table 3: Example Data packet using format 1.0

Byte #	ID	Data
1	<signature_1>	'M'
2	<signature_2>	'E'
3	<signature_3>	'P'
4	<flag>	0xNN
5	<packet_number_LSB>	0xNN
6	<packet_number>	0xNN
7	<packet_number>	0xNN
8	<packet_number_MSB>	0xNN
9	<CH_1_ECG_sample_1_LSB>	0xNN
10	<CH_1_ECG_sample_1_MSB>	0xNN
11	<CH_1_ECG_sample_2_LSB>	0xNN
12	<CH_1_ECG_sample_2_MSB>	0xNN
etc	etc	etc
9 + nes*2	<CH_2_ECG_sample_1_LSB>	0xNN

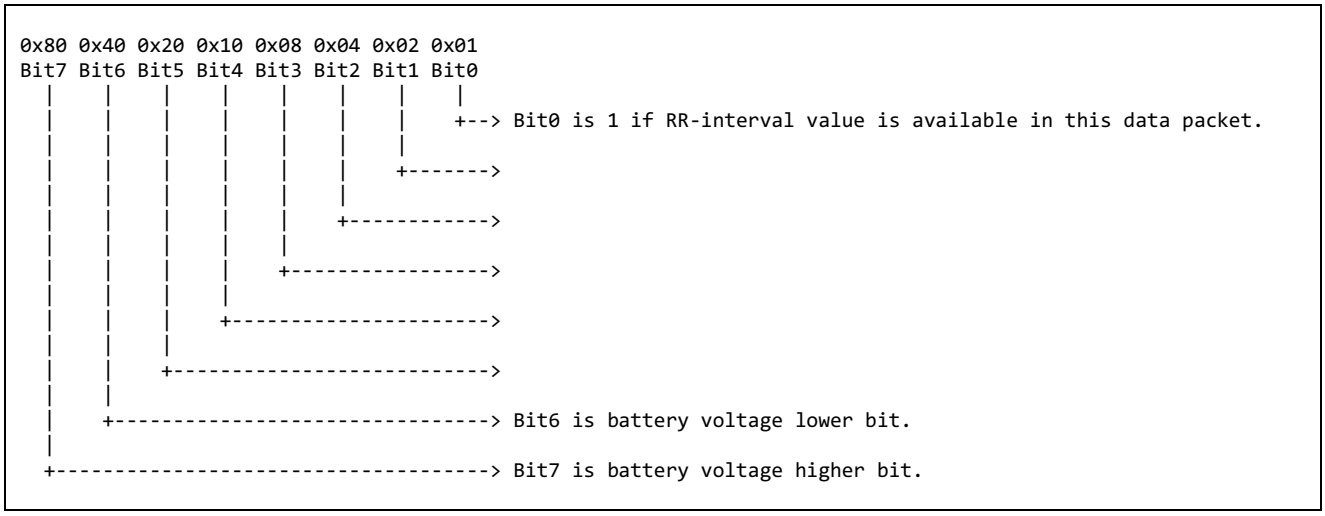
etc	<CH_2_ECG_sample_1_MSB>	0xNN
etc	<CH_2_ECG_sample_2_LSB>	0xNN
etc	<CH_2_ECG_sample_2_MSB>	0xNN
etc	etc	etc
9 + nes*4	<CH_3_ECG_sample_1_LSB>	0xNN
etc	<CH_3_ECG_sample_1_MSB>	0xNN
etc	<CH_3_ECG_sample_2_LSB>	0xNN
etc	<CH_3_ECG_sample_2_MSB>	0xNN
etc	etc	etc
9 + nes*nec*2	<Accelerometer_X_axis_sample_1_LSB>	0xNN
etc	<Accelerometer_X_axis_sample_1_MSB>	0xNN
etc	<Accelerometer_X_axis_sample_2_LSB>	0xNN
etc	<Accelerometer_X_axis_sample_2_MSB>	0xNN
etc	etc	etc
9 + nes*nec*2 + nas*2	<Accelerometer_Y_axis_sample_1_LSB>	0xNN
etc	<Accelerometer_Y_axis_sample_1_MSB>	0xNN
etc	<Accelerometer_Y_axis_sample_2_LSB>	0xNN
etc	<Accelerometer_Y_axis_sample_2_MSB>	0xNN
etc	etc	etc
9 + nes*nec*2 + nas*4	<Accelerometer_Z_axis_sample_1_LSB>	0xNN
etc	<Accelerometer_Z_axis_sample_1_MSB>	0xNN
etc	<Accelerometer_Z_axis_sample_2_LSB>	0xNN
etc	<Accelerometer_Z_axis_sample_2_MSB>	0xNN
etc	etc	etc
9 + nes*nec*2 + nas*6	<Marker_LSB>	0x01 / 0xFE
etc	<Marker_MSB>	0x80 / 0x7F
11 + nes*nec*2 + nas*6	<rr_LSB>	0xNN / 0x00
etc	<rr_MSB>	0xNN / 0x80
11 + nes*nec*2 + nas*6 + nrs*2	<Temperature_LSB>	0xNN
etc	<Temperature_MSB>	0xNN
11 + nes*nec*2 + nas*6 + nrs*2 + nts*2	Reserved byte 1	0xFF
etc	Reserved byte2	0xFF
etc	etc	Etc
25 + nes*nec*2 + nas*6 + nrs*2 + nts*2	Padding?	0xFF
etc	Padding?	0xFF
25 + nes*nec*2 + nas*6 + nrs*2 + nts*2 + npb	<Checksum LSB>	0xNN
etc	<Checksum MSB>	0xNN

3.2 Signature characters (bytes 1-3)

Every data packet starts with sequence ‘M’, ‘E’, ‘P’.

3.3 Flag (byte 4)

Flag is used to present important information (see below).



- **Bit0:** RR-interval has been detected and is transmitted in this packet.
- **Bits 7 and 6:** Battery voltage status as XY (X = bit 7, Y = bit 6). 11 = battery level > 75%, 10 = battery level is 25-75%, 01 = battery level 10-25% and 00 = battery level < 10% (measurement has to be stopped!).

Example:

- 0xC0 (1100 0000): Battery level > 75% and RR-interval not available.
- 0xC1 (1100 0001): RR-interval value available.
- 0x80 (1000 0000): Battery voltage level is 25-75%.
- 0x01 (0000 0001): RR-interval value available and battery level < 10%.

3.4 Packet number (bytes 5 to 8)

Data packets are identified with a running number. Four bytes are used for this. Byte 5 is the least significant byte (LSB) and byte 8 is the most significant byte (MSB). Packet number starts running from 1.

Example:

- 0x00000001: 1st packet
- 0x00000002: 2nd packet
- 0x00000003: 3rd packet

3.5 ECG data

Least significant byte (LSB) is first and followed by most significant byte (MSB). Raw data value can be from -32768 to 32767 (0x8000 to 0x7FFF in hexadecimal format).

Example:

- 0x8000: -32768
- 0xFFFF: -1
- 0x0000: 0
- 0x0001: 1
- 0x7FFF: 32767

3.6 Accelerometer data

Accelerometer data contains accelerometer samples from three axes(X, Y and Z). Values are transmitted least significant byte (LSB) first and followed by most significant byte (MSB). Data value can be from -32768 to 32767 (0x8000 to 0x7FFF in hexadecimal format).

Example:

- 0x8000: -32768
- 0xFFFF: -1
- 0x0000: 0
- 0x0001: 1
- 0x7FFF: 32767

3.7 Marker

Marker data indicates that the pushbutton on the device has been pushed. 0x8001 means that button is not pushed and 0x7FFE means that button is pushed.

3.8 RR-interval

RR-interval is time in milliseconds between two R-peaks. Two bytes are used for this. Intervals are sent with offset of -32768 ms i .e. value 0x83E8 (or -31678 in decimal) means 1000 ms interval.
Bit0 in flag is set to 1 if RR-interval is available in this data packet. Otherwise Bit0 is set to zero and RR interval is set to 0x8000 thats converts to 0 ms.

Example:

- 0x834B: 843 ms
- 0x8355: 853 ms
- 0x8337 : 823 ms

3.9 Temperature

Temperature is expressed in raw ADC values that can be converted to temperature. Using the following conversion values the temperature is linear between 35 and 45 ℃.
4095 = -53,3361 ℃
0 = 158,3488 ℃

3.10 Reserved

14 bytes are reserved. Currently set as 0xFF.

3.11 Padding

2 padding bytes might be required to make packet size divisible by 4 as required by some systems. Set as 0xFF.

3.12 Checksum

Checksum is CRC (CCITT) checksum calculated from all the previous bytes in the packet including signature bytes.

4 ONLINE MODE

In online mode Faros sends data continuously using Bluetooth. In online mode only stop measurement commands are accepted.

4.1 Command set

Table 4: Online mode commands and responses

Refer to Chapter	Command	Command length	Response	Response length	Description
4.1.1	wbaom0\r	7	wbaack\r	7	Stop measurement and power off device
4.1.1	wbaoms\r	7	wbaack\r	7	Stop measurement and return to idle state
4.1.2	wbaomp\r	7	no response	0	Pause sending data
4.1.3	wbaomc\r	7	no response	0	Continue sending data

4.1.1 Stop measurement / power off device

Measurement is stopped when device receives "wbaom0\r" command. Device responses "wbaack\r" if command is successfully received. Device is automatically powered off.

If it is not desirable to power off the device the measurement can be stopped with "wbaoms\r" command. Device responses "wbaack\r" if command is successfully received. Device returns to idle state.

4.1.2 Pause sending data

When device is sending data, data transmission can be paused by sending command “wbaomp\r”.

4.1.3 Continue sending data

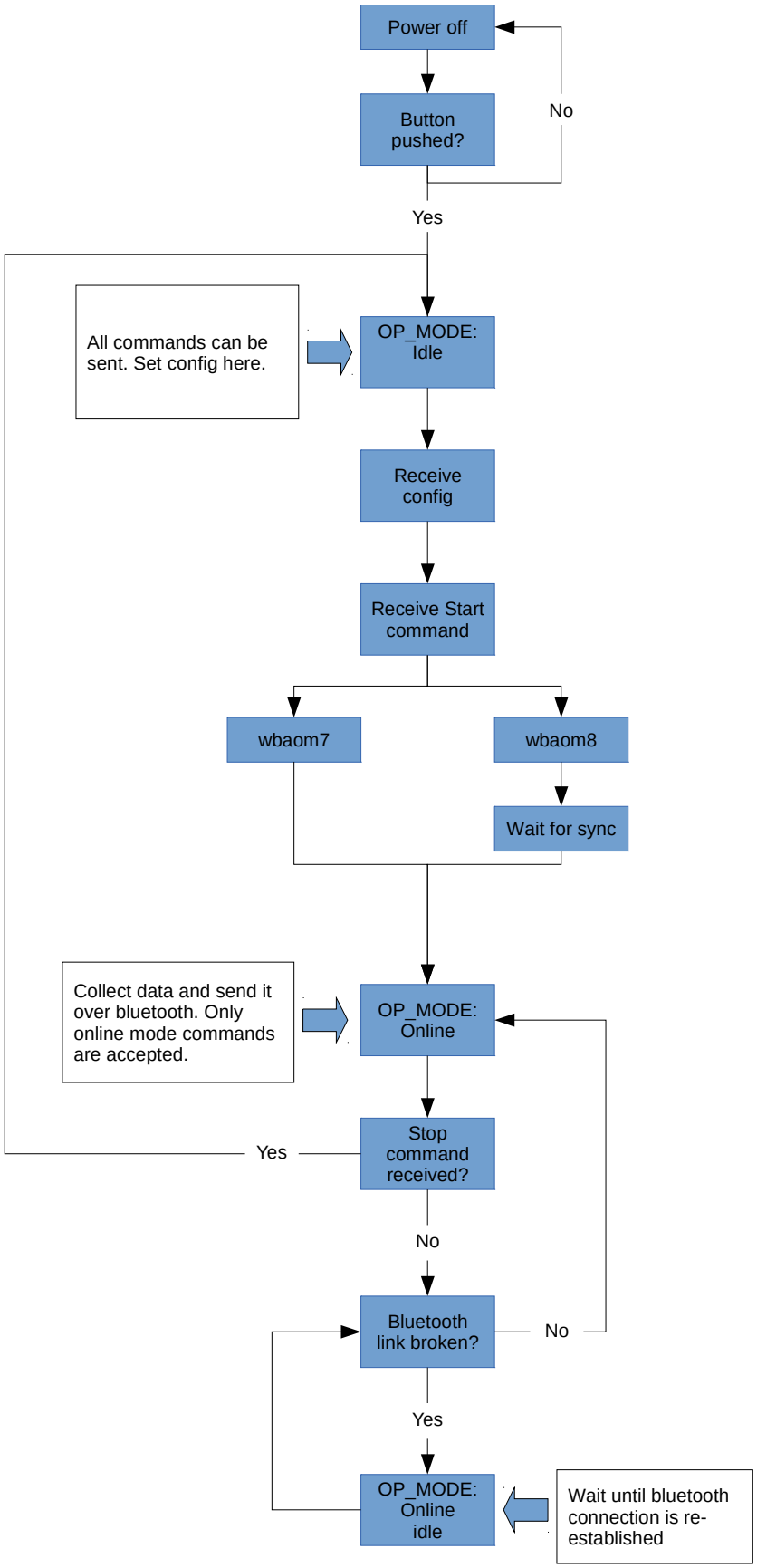
When data transmission is paused, data transmission can be continued by sending command “wbaomc\r”.

4.2 Device indication lights in online mode

Table 5: Device indication lights in online mode

Light function	Description
● — 2 sec — ●	Bluetooth connection is broken.
● — 1 sec — ●	Device is recording and sending data
● —0.25 sec — ●	Pushbutton is pressed.
2x● — 3 sec —2x ●	Battery voltage is low.

4.3 Online mode flow chart



5 VERSION HISTORY

Table 6: Version history

Version	Date	Author	Description
1.0	27.11.2014	SH	First revision.
1.1	30.4.2015	SH	Added information how to convert temperature readings to ℃