ATB Open Biosignal Profile (ATB-OBP) — Version 1.0

Status: Release 1.0 · **Date:** 4 November 2026 · **Owner:** HMS Health Mobile Software / Auto Train Brain Inc. · **Contact:** info@healthmobilesoftware.com

ATB-OBP is an open, vendor-neutral Bluetooth Low Energy (BLE) GATT profile for multi-channel EEG and related biosignal devices. A device that implements this profile connects to ATB Desktop (Windows and macOS) — and later to the ATB mobile apps — **without any vendor driver or SDK**. The application discovers the device, reads a self-describing JSON record, starts the stream and immediately uses the device for live EEG monitoring, recordings, QEEG measurements and EEG-based brain exercise sessions in clinical EEG software.

The key words MUST, MUST NOT, SHOULD, SHOULD NOT and MAY are used as in RFC 2119.

1. Scope and design goals

- **One profile, any hardware:** 1–32 channels, 128–4096 Hz, dry / dry-active / gel / saline electrodes.
- **Self-describing:** channel labels, sample rates, scaling and features are read from the device; the app needs no per-model code.
- **Simple firmware:** fixed little-endian binary packets; one notification per data packet; no compression.
- **Robust:** every packet carries a sequence number and a sample index, so the app detects and repairs loss exactly.
- **Extensible:** unknown JSON keys are ignored; vendor features use the `x-` prefix; optional characteristics may be absent.

Out of scope for 1.0: on-device signal processing results, stimulation output, firmware update (use the vendor's own DFU service), more than 32 channels (planned for 2.0).

2. Conformance levels

Level	Requirement
Core (REQUIRED)	Service, Device Info (§5), Control Point with `START_STREAM` / `STOP_STREAM` (§6), EEG Data (§7), timing (§9), at least one sample rate ≥ 128 Hz.
Recommended	Status (§8.2), impedance *or* contact quality (§8.1), `SYNC_TIME`, `IDENTIFY`, standard Battery Service 0x180F, Device Information Service 0x180A, LE Secure Connections.
Optional	Aux (IMU / PPG, §8.4), Events / markers (§8.3), `SET_RATE`, `SET_CHANNEL_MASK`, `MARKER`.

A device is **"ATB-OBP 1.0 Core compatible"** when it passes every Core check of the in-app conformance test (§11).

3. GATT layout

3.1 UUIDs

All ATB-OBP UUIDs share one 128-bit base. Replace `xxxx` with the 16-bit short code:

```
a7b1xxxx-0b1e-4e0e-8a7b-41544200b1e0        ("415442" = ASCII "ATB")
```

Short	UUID	Name	Properties	Level
`0000`	`a7b10000-0b1e-4e0e-8a7b-41544200b1e0`	**ATB-OBP Service** (primary)	—	Core
`0001`	`a7b10001-0b1e-4e0e-8a7b-41544200b1e0`	Device Info	Read	Core
`0002`	`a7b10002-0b1e-4e0e-8a7b-41544200b1e0`	Control Point	Write (with response), Indicate	Core
`0003`	`a7b10003-0b1e-4e0e-8a7b-41544200b1e0`	EEG Data	Notify	Core
`0004`	`a7b10004-0b1e-4e0e-8a7b-41544200b1e0`	Impedance / Contact	Notify	Recommended
`0005`	`a7b10005-0b1e-4e0e-8a7b-41544200b1e0`	Status	Read, Notify	Recommended
`0006`	`a7b10006-0b1e-4e0e-8a7b-41544200b1e0`	Aux (IMU / PPG)	Notify	Optional
`0007`	`a7b10007-0b1e-4e0e-8a7b-41544200b1e0`	Events / Markers	Notify	Optional

Standard SIG services that MAY be added alongside: Battery Service `0x180F` (Battery Level `0x2A19`), Device Information Service `0x180A`.

3.2 Advertising

- The device MUST include the ATB-OBP Service UUID (128-bit) in its advertising data **or** scan response, so the app can filter devices by service.
- The device SHOULD advertise a human-readable Complete Local Name (e.g. `AcmeEEG-8 1234`; the last 4 characters of the serial help identify one of several units).
- Advertising interval while waiting for a connection: 100–250 ms recommended.

3.3 Byte order

All multi-byte integer and float fields are **little-endian**. Signed integers are two's complement.

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4. Connection sequence (what the app does)

1. Scan with filter `services = [ATB-OBP Service]`; the user picks the device in the app.
2. Connect; exchange MTU (the app's BLE stack requests the maximum; see §9.1).
3. **Read Device Info** (§5), parse and validate it. Validation errors abort the connection and are shown in the conformance test.
4. Enable indications on Control Point; enable notifications on Status, Impedance and Events if present. Read Status once.
5. Enable notifications on EEG Data.

6. If `sync_time` is listed in features: send `SYNC_TIME`.
7. Send `START_STREAM(defaultRate, mask = all eeg+eog channels, format)`; wait for the response indication (timeout 3 s).
8. Stream. On user disconnect: send `STOP_STREAM`, wait ≤ 1.5 s for the response, then disconnect.

Firmware MUST tolerate steps 4–5 in any order and MUST NOT start streaming before `START_STREAM`.

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5. Device Info characteristic (`0001`)

A UTF-8 encoded JSON object (no BOM; trailing NUL bytes allowed). The value MAY be longer than the ATT MTU — the client uses ATT Read Blob (long read) automatically. Maximum length 2048 bytes. The value MUST NOT change while connected.

5.1 Fields

Key	Type	Req.	Meaning
`obp`	string `"major.minor"`	**yes**	Profile version implemented. For this spec `"1.0"`.
`vendor`	string ≤ 64	**yes**	Manufacturer name.
`model`	string ≤ 64	**yes**	Model name.
`serial`	string ≤ 64	recommended	Unit serial number (no personal data).
`firmware`	string ≤ 32	recommended	Firmware version.
`hardware`	string ≤ 32	no	Hardware revision.
`electrodes`	`"dry"` | `"dry-active"` | `"gel"` | `"saline"`	recommended	Selects the app's signal-quality and artifact profile.
`rates`	number[]	**yes**	Supported sample rates in Hz (64–4096). At least one MUST be ≥ 128. 250, 256, 500 or 512 recommended.
`defaultRate`	number	recommended	Rate used by the app; MUST be in `rates`.
`formats`	string[]	**yes**	Sample formats supported: `"int16"`, `"int24"`, `"float32"`.
`format`	string	recommended	Preferred format (MUST be in `formats`).
`lsb_uV`	number	**yes** for int formats	Microvolts per LSB at the device output (after gain). µV = raw × `lsb_uV`.
`range_uV`	number	no	± input range in µV.
`reference`	string	no	Reference electrode / montage, e.g. `"Cz"`, `"linked-ears"`, `"A1"`.
`ground`	string	no	Ground / bias electrode, e.g. `"Fpz"`.
`channels`	object[] (1–32)	**yes**	One entry per hardware channel, **in channel-index order**. See §5.2.
`maxFramesPerPacket`	number 1–255	recommended	Largest `nFrames` the device sends (§7).
`features`	string[]	recommended	Capability list, §5.3.
`filters`	object	no	`{ "hp_Hz": 0.5, "lp_Hz": 100, "notch_Hz": null }` — analog/digital filtering applied by the device.

Unknown keys MUST be ignored by the app; vendors MAY add keys prefixed `x-` (e.g. `"x-acme-gain": 24`).

5.2 Channel entries

```
{ "label": "Fp1", "type": "eeg" }
```

- `label`: electrode name in the **international 10-20 / 10-10 system** (e.g. `Fp1`, `F3`, `Cz`, `O2`, `TP9`). Legacy names `T3/T4/T5/T6` are accepted and mapped to `T7/T8/P7/P8`. Labels MUST be unique.
- `type`: `eeg` (default) · `ref` · `eog` · `emg` · `ecg` · `aux`. The app streams `eeg` and `eog` channels by default; at least one `eeg` channel is required.
- The channel's **index** (0-based position in the array) is its bit in the channel mask and its column in data packets.

5.3 Features

Feature	Meaning
`impedance`	Impedance in kΩ via `IMPEDANCE_START` (§8.1, format 1).
`contact_quality`	Contact quality 0–100 % instead of kΩ (§8.1, format 2) — typical for dry electrodes.
`impedance_during_stream`	EEG keeps streaming while impedance is measured.
`status`	Status characteristic present.
`events`	Events characteristic present.
`aux.accel` / `aux.gyro` / `aux.ppg`	Aux characteristic streams these types.
`sync_time` / `marker` / `identify` / `set_rate` / `channel_mask`	Control Point opcodes supported.
`battery_service` / `dis`	SIG services 0x180F / 0x180A present.
`x-…`	Vendor specific.

5.4 Example

```
        {
          "obp": "1.0",
          "vendor": "Acme Neuro",
          "model": "AN-8",
          "serial": "AN8-000123",
          "firmware": "1.2.0",
          "hardware": "rev C",
          "electrodes": "dry",
          "rates": [250, 500],
          "defaultRate": 250,
          "formats": ["int24"],
          "format": "int24",
          "lsb_uV": 0.02235,
          "range_uV": 187500,
          "reference": "linked-ears",
          "ground": "Fpz",
          "channels": [
            { "label": "Fp1", "type": "eeg" }, { "label": "Fp2", "type": "eeg" },
            { "label": "C3",  "type": "eeg" }, { "label": "C4",  "type": "eeg" },
            { "label": "P3",  "type": "eeg" }, { "label": "P4",  "type": "eeg" },
            { "label": "O1",  "type": "eeg" }, { "label": "O2",  "type": "eeg" }
          ],
          "maxFramesPerPacket": 9,
          "features": ["contact_quality", "status", "sync_time", "identify",
"battery_service"],
          "filters": { "hp_Hz": 0.5, "lp_Hz": 100, "notch_Hz": null }
        }
```

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6. Control Point characteristic (`0002`)

The app writes a command (Write **with** response). The device answers every command with **one indication** on the same characteristic.

6.1 Command format

Byte	Field
0	Opcode (u8)
1…	Parameters (little-endian)

Opcode	Name	Parameters	Level
`0x01`	`START_STREAM`	`rate_Hz u16` · `channelMask u32` · `format u8` (0 = device default, 1 = int16, 2 = int24, 3 = float32)	Core
`0x02`	`STOP_STREAM`	—	Core
`0x03`	`IMPEDANCE_START`	—	Recommended
`0x04`	`IMPEDANCE_STOP`	—	Recommended
`0x05`	`SET_RATE`	`rate_Hz u16` (only while not streaming)	Optional
`0x06`	`SET_CHANNEL_MASK`	`channelMask u32` (only while not streaming)	Optional
`0x07`	`SYNC_TIME`	`unixTime_ms u64`	Recommended
`0x08`	`MARKER`	`code u16`	Optional
`0x09`	`IDENTIFY`	`seconds u8` (blink LED / vibrate)	Recommended
`0x0A`	`GET_STATUS`	—	Recommended

`channelMask`: bit *i* selects `channels[i]`. Bits ≥ channel count MUST be ignored. A mask of 0 is `INVALID_PARAM`.

6.2 Response indication

Byte	Field
0	`0x80` (response code)
1	Request opcode
2	Result (u8)
3…	Optional response data

Result	Name	When
`0x00`	SUCCESS	Command executed.
`0x01`	NOT_SUPPORTED	Unknown or unsupported opcode.
`0x02`	INVALID_PARAM	Rate not in `rates`, mask 0, unsupported format…
`0x03`	INVALID_STATE	e.g. `SET_RATE` while streaming, `START_STREAM` while already streaming with different parameters.
`0x04`	FAILED	Hardware error (also set Status error code).

Response data:

- `SYNC_TIME` → `sampleIndex u32` of the device at reception (lets the app align device sample clock to wall time).
- `GET_STATUS` → the 8-byte Status payload (§8.2).
- `START_STREAM` → MAY return `rate_Hz u16 · channelMask u32 · format u8` actually applied.

Timing: the response SHOULD be indicated within 200 ms (MUST within 3 s). `START_STREAM` while already streaming with identical parameters SHOULD return SUCCESS (idempotent). After `START_STREAM` the first data packet MUST start with `firstSampleIndex = 0`.

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7. EEG Data characteristic (`0003`)

One notification = one packet = a 10-byte header + `nFrames` frames. A **frame** is one sample of every channel in the active mask, in ascending channel-index order.

7.1 Packet layout

Offset	Size	Field	Notes
0	u8	`format`	Low nibble: `0x01` int16 · `0x02` int24 · `0x03` float32 (value already in µV). High nibble reserved = 0.
1	u16	`seq`	Packet counter, +1 per packet, wraps 65535 → 0. Resets to 0 on `START_STREAM`.
3	u32	`firstSampleIndex`	Index of the first frame in this packet since `START_STREAM` (sample clock), wraps at 2^{32}.
7	u8	`nFrames`	Frames in this packet (1–255, ≤ `maxFramesPerPacket`).
8	u8	`nChannels`	Channels per frame = popcount(active mask).
9	u8	`flags`	bit0 LEAD_OFF (any channel off) · bit1 CLIPPING · bit2 MARKER (an Events record refers to this packet) · bit3 LOW_BATTERY · bits4–7 reserved = 0.
10	n	samples	`nFrames × nChannels × bytesPerSample`, frame-major (F0C0, F0C1 … F0Cn, F1C0 …).

`bytesPerSample`: int16 = 2, int24 = 3 (little-endian, sign-extended from bit 23), float32 = 4 (IEEE-754).

Scaling: `µV = raw × lsb_uV` for int formats; float32 values are µV directly.

7.2 Sizing packets

The ATT notification payload is `MTU − 3` bytes. The firmware MUST choose `nFrames` so that `10 + nFrames × nChannels × bytesPerSample ≤ MTU − 3`.

MTU	Channels	Format	Max frames / packet	Packets/s at 250 Hz
247	8	int24	9	~28
247	8	int16	14	~18
247	4	int24	19	~13
247	16	int24	4	~63
185	8	int24	7	~36
23 (default)	2	int16	2	125

Firmware SHOULD send a packet at least every 40 ms even if it is not full (latency, §9.2).

7.3 Golden packets (for firmware unit tests)

int16, `seq` = 0x0102, `firstSampleIndex` = 1000, 2 frames × 2 channels, samples [100, −100], [32767, −32768]:

```
01 02 01 E8 03 00 00 02 02 00 64 00 9C FF FF 7F 00 80
```

int24, `seq` = 0, index 0, LEAD_OFF set, 1 frame × 3 channels, samples [1, −1, −8388608]:

```
02 00 00 00 00 00 00 01 03 01 01 00 00 FF FF FF 00 00 80
```

7.4 Loss handling (app side, informative)

- `seq` gap → packets lost; `firstSampleIndex` gap → exact number of frames lost.
- Gaps ≤ 1 s are bridged by linear interpolation so filters and spectra stay continuous; the loss is counted and reported (loss %).
- Gaps > 1 s break the stream (discontinuity); recordings mark the break.
- Packets with an older `firstSampleIndex` (duplicates / reordered) are dropped.
- The device MUST NOT renumber samples after a buffer overrun: if frames are dropped on the device, skip their indices (so the app sees the gap) and increment the Status `droppedPackets` counter.

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8. Optional characteristics

8.1 Impedance / Contact (`0004`, Notify)

Sent while impedance mode is active (`IMPEDANCE_START` … `IMPEDANCE_STOP`), at least once per second.

Offset	Size	Field
0	u8	`format`: `0x01` kΩ (u16 per channel) · `0x02` contact quality 0–100 % (u8 per channel)
1	u8	`firstChannel` (index into `channels`)
2	u8	`count`
3	…	values: format 1 → u16 kΩ, `0xFFFE` = open / lead-off, `0xFFFF` = unknown; format 2 → u8 0–100, `0xFF` = unknown

Large channel counts MAY be split across several notifications using `firstChannel`. Unless `impedance_during_stream` is listed, the device MAY pause EEG data during impedance mode and MUST resume it on `IMPEDANCE_STOP` (continuing `seq`/`firstSampleIndex` numbering, which the app treats as a gap).

App colour coding: kΩ ≤ 20 green, ≤ 50 amber, > 50 red; quality ≥ 70 green, ≥ 40 amber.

8.2 Status (`0005`, Read + Notify)

8 bytes. Notify on change and at least every 10 s while connected.

Offset	Size	Field
0	u8	Battery % (0–100, `0xFF` unknown)
1	u8	Flags: bit0 CHARGING · bit1 STREAMING · bit2 IMPEDANCE · bit3 LOW_BATTERY · bit4 ERROR
2	u8	State: 0 idle · 1 streaming · 2 impedance · 3 error
3	u8	Error code (0 = none; vendor-defined otherwise)
4	u32	Dropped packets (device-side overruns since `START_STREAM`)

Safety recommendation: devices SHOULD NOT stream EEG while charging from mains (mains noise and electrical safety); report CHARGING so the app can warn.

8.3 Events / Markers (`0007`, Notify)

7 bytes per event.

Offset	Size	Field
0	u8	Type: 1 marker echo (from `MARKER`) · 2 button press · 3 lead-off change · 4 hardware trigger input
1	u32	`sampleIndex` (on the EEG sample clock)
5	u16	Code (marker code, button id, channel index, trigger value)

8.4 Aux — IMU / PPG (`0006`, Notify)

Offset	Size	Field
0	u8	Type: `0x10` accelerometer (mg) · `0x11` gyroscope (0.01 °/s) · `0x12` PPG (raw)
1	u16	`seq`
3	u32	`sampleIndex` on the **EEG** sample clock (for alignment)
7	u8	`nFrames`
8	u8	`nAxes` (accel/gyro 3, PPG 1–3)
9	…	int16 samples, frame-major

ATB Desktop 1.11 ignores Aux data; it is reserved for motion-artifact rejection and HRV in a later release.

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9. Timing and performance

9.1 MTU and connection parameters

- Support ATT MTU exchange up to **247** (BLE 4.2 Data Length Extension). The device MUST still work at the default MTU 23 by sending smaller packets.
- Connection interval 7.5–30 ms recommended (15 ms typical); slave latency 0 while streaming; supervision timeout 2–4 s.
- 2M PHY SHOULD be supported for ≥ 16 channels or ≥ 500 Hz.

9.2 Sampling and latency

Item	Requirement
Sample rate	≥ 128 Hz (Core); 250 / 256 / 500 Hz recommended
Rate accuracy	Effective rate within **±2 %** of nominal (crystal-derived sample clock; ±50 ppm recommended)
Packet loss	≤ **0.5 %** frames over 10 min at 1 m line of sight
Latency	Sample-to-notification ≤ 100 ms (Core: max gap between packets ≤ 100 ms); ≤ 50 ms recommended
Jitter	Inter-packet arrival standard deviation ≤ 20 ms recommended
Channels	All channels sampled simultaneously (or skew ≤ 1 sample)
Data rate check	8 ch × 250 Hz × int24 = 6 kB/s payload — comfortably within BLE 1M PHY

9.3 Signal quality (recommendations)

- Input-referred noise ≤ 1 µV RMS (0.5–40 Hz); CMRR ≥ 100 dB; resolution ≤ 0.1 µV/LSB.
- Do not apply a mains notch filter on the device unless reported in `filters`; the app applies 50/60 Hz notch by region.
- High-pass ≤ 0.5 Hz; anti-alias low-pass < 0.45 × sample rate.

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10. Security and privacy

- LE Secure Connections pairing (Just Works or Passkey) is RECOMMENDED; the profile also works unpaired for evaluation units.
- The device MUST NOT store or transmit personal or health information about the wearer. `serial` identifies the hardware only.
- The Control Point MUST reject malformed commands with INVALID_PARAM and never crash or reboot.
- Firmware updates are out of scope; use the vendor's own DFU service (it MUST NOT be reachable through ATB-OBP characteristics).

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11. Conformance checklist (in-app test)

ATB Desktop → Clinic → device card **"ATB-OBP Bluetooth device" → 🧪 Conformance test** runs these checks live and exports a JSON report (*Save report*). Send the report to info@healthmobilesoftware.com to be listed as compatible.

ID	Level	Check	Pass criterion
C1	Core	Device Info JSON	Valid JSON, `obp` major = 1, required fields present, rates/format/lsb consistent, unique labels, ≥ 1 EEG channel. Warnings (e.g. non 10-10 label) do not fail.
C2	Core	START_STREAM	Response SUCCESS within 3 s.
C3	Core	Sample rate	Effective rate within ±2 % of `defaultRate` (warn ±5 %), ≥ 10 s streaming.
C4	Core	Frame loss	≤ 0.5 % (warn ≤ 2 %).
C5	Core	Packet gap	Longest gap ≤ 100 ms (warn ≤ 250 ms).
C6	Core	STOP_STREAM	Response SUCCESS on disconnect.
C7	Core	10-10 labels	All EEG labels map to 10-10 names (warning only).
O1	Optional	Status	Status read/notify decodes.
O2	Optional	Impedance / contact	At least one impedance/quality notification received.

Firmware-side self test: reproduce the golden packets of §7.3 byte-for-byte.

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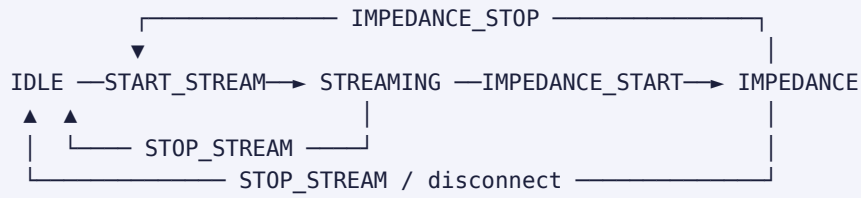
12. Versioning

- `obp` = `"major.minor"`. Minor versions only **add** optional fields, opcodes, characteristics or flag bits; a 1.x app accepts any 1.y device (unknown parts ignored, a newer minor is reported as a warning).
- A major version change (2.0) may change packet layouts; it will use a new service UUID short code so 1.x and 2.x can coexist on one device.
- Reserved bits and bytes MUST be sent as 0 and ignored on receipt.

13. Reference material

File	Purpose
`atb_obp.h`	C header: UUIDs, opcodes, packed structs, packet builder for embedded firmware.
`reference/atb_obp_sim.py`	Reference BLE peripheral (Python, `bless`) that simulates an 8-channel device — test the app without hardware.
ATB Desktop `src/shared/obp/protocol.ts`	The app's decoder and validator (normative behaviour of §5–§7 on the client side).

Appendix A — Minimal firmware state machine



- On disconnect: stop streaming, keep advertising.
- On `START_STREAM`: reset `seq` and `firstSampleIndex` to 0, apply rate/mask/format, respond SUCCESS, then start notifications.

Appendix B — Example timeline

```
App  → Read 0001                          ← {"obp":"1.0",...}
App  → CCCD 0002 = indicate, 0003/0004/0005 = notify
App  → 0002: 07 <unix ms u64>             ← 80 07 00 <sampleIndex u32>        (SYNC_TIME)
App  → 0002: 01 FA 00 FF 00 00 00 02      ← 80 01 00                          (START 250 Hz, 8
ch, int24)
     ← 0003: 02 00 00 00 00 00 00 09 08 00 <216 bytes>   seq 0, idx 0
     ← 0003: 02 01 00 09 00 00 00 09 08 00 <216 bytes>   seq 1, idx 9
     …
App  → 0002: 02                           ← 80 02 00                          (STOP)
```