EXPLORE

User Manual

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Acronyms and Abbreviations

API	Application user interface
ECG	Electrocardiogram
EEG	Electroencephalogram
EMG	Electromyography
ExG	EEG / EMG / ECG
SPS	Samples per second

Definitions

Recording session	The period in which the device is recording. For each recording session, starting automatically at device start up, a bin file in the flash memory will be generated.
Advertising	As part of the Bluetooth connection process, the Explore device will advertise that it is available for a connection to a host machine. When it is connected, the Explore device becomes the slave device. Reference Bluetooth Core Specification Version 4.0 for more information.
Host machine	The computer or smartphone that initiates the connection and is the master in the connection with the Explore device.
Pairing	Establishing a connection between two Bluetooth devices.
Online mode	Data will be transmitted to the host machine in addition to being stored on the device memory in duplicate. The host machine can send data and commands to the device.
Offline mode	Data will be stored only in the device memory. No host machine is connected to the device.

1 Introduction

1.1 Intended Use

Mentalab Explore is a biosignal acquisition device developed mainly for research, development, and educational purposes. It is not intended for medical use. Mentalab Explore is used by scientists, developers, innovators, and students around the world in their own custom applications.

1.2 Release Notes

Date	Firmware	Explorepy	Documentation	Changes
31.08.2020	2.1.4	1.1.0	MLExploreV1.1	First release

1.3 Product Certification

Mentalab hereby declares that the Explore product series is in accordance with the requirements and relevant provisions of EU directives:

2014/30/EU

2014/53/EU

2015/863/EU

1.4 Safety

Preventing Misuse

Any operator of a Mentalab Explore device should read the instruction manual specific to the device and API versions. The device is only to be operated according to the instructions.

Mentalab Explore is not intended for medical use, including any diagnostic or therapeutic applications. Mentalab Explore should not be used with implanted electrical cardiac or neural stimulators (pacemaker, tDCS, tACS, DBS, etc).

Mentalab Explore is not protected against electrical defibrillation. The device and electrodes must be detached from the subject's skin beforehand.

Before use, inspect the device and accessories thoroughly for possible damage to connectors, sockets, and cables. Especially, ensure that the electrode cables are intact. Any part of the equipment must be replaced immediately if damaged or not working correctly.

The device and its accessories must not be exposed to increased mechanical stress.

Do not open or modify the device, it will void the warranty.

Using controls, adjustments, procedures, connections, or signal types other than those specified in the Explore documentation may result in electrical and mechanical hazards.

Only use Mentalab approved accessories with this device. If an accessory is not listed, please contact us for technical support.

Battery

While being charged or connected to a PC / tablet, the device should not be connected to any subject.

The external power supply must fulfill the IEC/EN 60950-1 and SELV requirements to be used safely with the device. Do not charge your device with anything other than the USB port of a certified laptop / PC or a certified mini USB charger. Using a non-certified power supply can lead to electrical and fire hazards.

Users should not attempt to replace or disconnect the Explore's battery.

Environment Precautions

The Explore device is not designed for use in inflammable or explosive environments.

It should be used at room temperature. Exposure to conducting material, liquid, fire or heat above 45° C can lead to overheating or electrical discharge.

Mentalab Explore is not to be used in wet environments either, as liquid intrusion can cause electrical hazards. When applying electrodes on the subject's head, the cap and the subject's hair should be dry.

Protect the device and electrodes from electrostatic discharge and take all precautions regarding electromagnetic compatibility.

Signal Transmission

The operation of the movement sensors and wireless transmission can be compromised within shielded rooms. It is not possible to communicate with the device from outside of the shield.

Mentalab Explore uses the 2.4 GHz band for wireless transmission, so nearby Bluetooth and wireless devices can cause interference. Therefore, ensure that enough transmission bandwidth is available in your environment. We recommend working in environments with low wireless and noise interference for better performance.

If the equipment is not installed according to the instructions, it may interfere with nearby devices. If it does, which can be determined by turning the equipment off and on, try the following measures:

- Reorient or relocate the receiving device.
- Increase the space between the Explore equipment and other wireless devices.
- Use the equipment with proper shielding, especially if a device with high wattage is nearby.
- Consult the Explore technical support.

Equipment Maintenance

Mentalab Explore uses lightweight, highly flexible cables to provide comfort and easy cap mounting, especially for multi-channel recording. These cables are sensitive and need to be treated with special care. Following these guidelines will prolong the lifetime of ExG electrodes:

- Do not pull on the electrodes' cables and avoid knots. Do not cut, kink or pinch electrode cables; light bending is safe.
- Avoid exposure to direct sunlight and chemicals.
- Clean the cables and electrodes from remaining gel, disinfectant, paste or other residues. Do not use detergents with chlorine or other corrosive agents to clean the equipment.
- Protect the Explore unit from liquid contamination. Ensure that the whole equipment is completely dry before storing.

2 Technical Information

2.1 Explore Outline

The Mentalab Explore device is a powerful and flexible solution for mobile biosignal recordings. It combines research-grade precision with great usability in a mobile format. We offer several easy-to-use, open-source APIs. Mentalab Explore and its APIs provide you with rich and easily integrable data pipelines, so you can focus on your application. You can choose to work with data offline or in real-time. Data can be streamed to any host device with a Bluetooth module, such as computers and smartphones. Besides precise multi-channel-ExG, Mentalab Explore also contains a comprehensive set of position and device sensors.

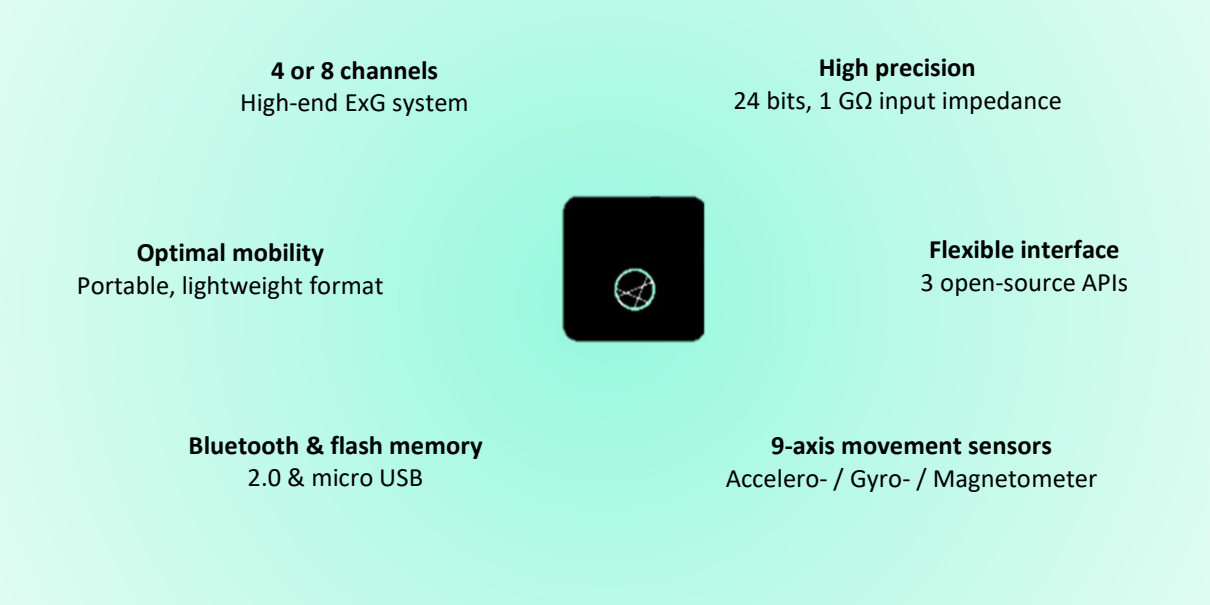


Figure 1. Explore system overview

2.2 Contents

Based on your order, the box you received should include:

- 1 Mentalab Explore device
- 1 USB 2.0A to micro-USB cable
- A quick-start guide
- Electrodes and caps of your choice
- Optionally: electrode gel and cleaning solution

2.3 Device Specifications

No. of Channels	4 or 8
ExG Sampling Rate	250 (default), 500 or 1000 sps (in beta phase)
Operation Time	8h online recording, 12h offline recording
Differential Input Range	400 mV
Input Impedance	> 1 GΩ
Resolution	24 bits
USB Output Interface	USB 2.0
Additional Sensors	Magneto- / Gyro- / Accelerometer: 20 sps Device Temperature, Battery: 1 sps
Flash Memory Size	512 MB
Dimensions	41mm * 42mm * 18mm
Bluetooth Range	10 m

The following picture shows the Explore device label. You can also find it on the Explore case and on the box. The last four digits on the label define the device's Bluetooth name. For example, the label below corresponds to a device whose Bluetooth ID is "Explore_1438":

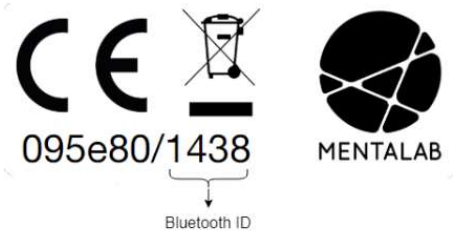


Figure 2. Example device label

3 Operation Instructions

3.1 Operating Modes

Mentalab Explore has two main operating modes: offline and online. When in offline mode, the device collects data and stores it in its internal flash memory. Users can extract the recordings from the flash memory via a micro-USB cable after the recording. Data can be retrieved and transformed with different tools provided in the APIs.

During online mode, data is transmitted via Bluetooth in real-time, enabling the user to collect, monitor, and visualize data, and to configure the device through one of the available APIs (explorepy, exploreMATLAB and libexplorecpp). In this mode, the Explore device sends the data and communicates in configuration packets with the API on the host machine.

While you can start using the device right out of the box, we recommend charging it for at least 1 hour. To charge the device, connect the micro-USB cable to a compliant source. The green LED indicates sufficient battery. After charging, unplug the device from the power source.

3.2 First Setup

Set up the measurement electrodes on your subject in your preferred configuration. Each channel (1-4 or 1-8) is recorded against the reference electrode. The electrodes are configured in the order depicted below. In a 4-channel device, channels 5-8 are inactive.

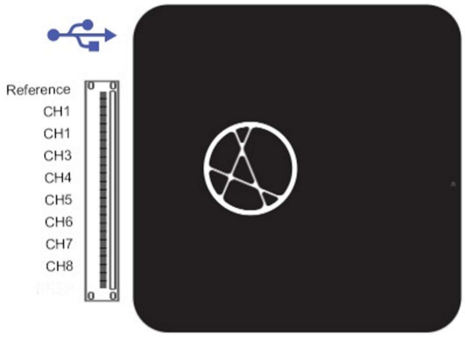


Figure 3. Device configuration

Push the button to turn on your Explore system. At system start, the LED shows the battery level (green > 60 %, yellow 30 - 60 %, red < 30 % charge remaining).

Upon normal start, the device begins to record on the flash memory immediately. It starts advertising and waits for a Bluetooth connection to a host machine. During advertising mode, the LED blinks in blue at 2 Hz (twice per second). If no connection is established after 4 minutes, the device will automatically go to offline mode. In this state, the LED blinks in green at a rate of 1 Hz and the Explore keeps recording data in the internal memory. You can leave the device in recording mode for as long as you wish. With a full battery, recording for up to 12 hours is possible. If you want to start in offline mode directly, turn on the device with three button pushes.

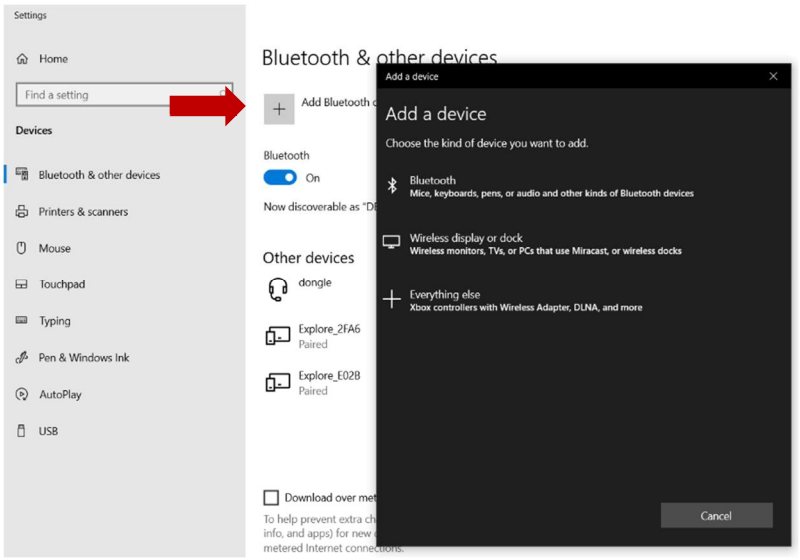
If you press the device's button once during recording, a marker packet with the event timestamp is set and written in the data. This can be used for labelling certain events, for example the beginning and end of recording periods.

To turn off the device, keep the button pressed until the LED turns red. The device will shut down with three red blinks.

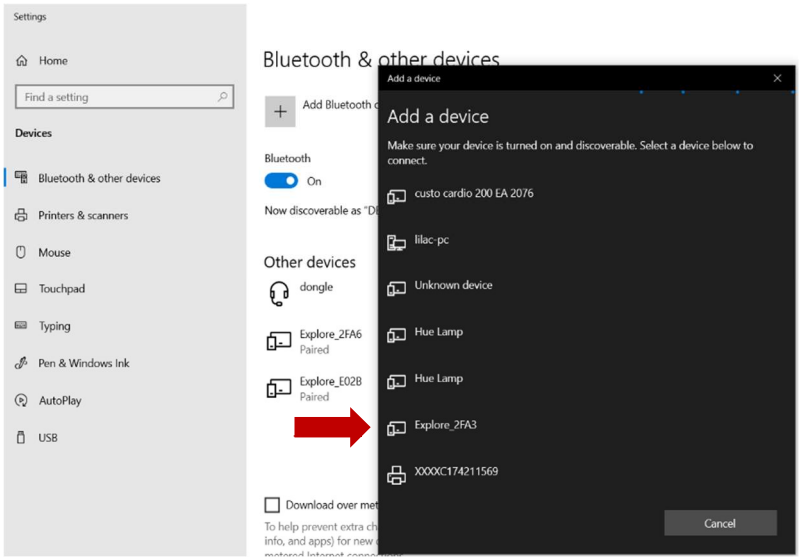
Wireless Transmission

If you want to stream and record data on your PC or smartphone, you must first pair your Explore device. Here is an example of how to do this on Windows:

First, go to your Bluetooth settings and choose "Add Bluetooth device".



Then, add the Bluetooth device whose name corresponds to your Explore (i.e. Explore_ followed by the last 4 digits on the device label).

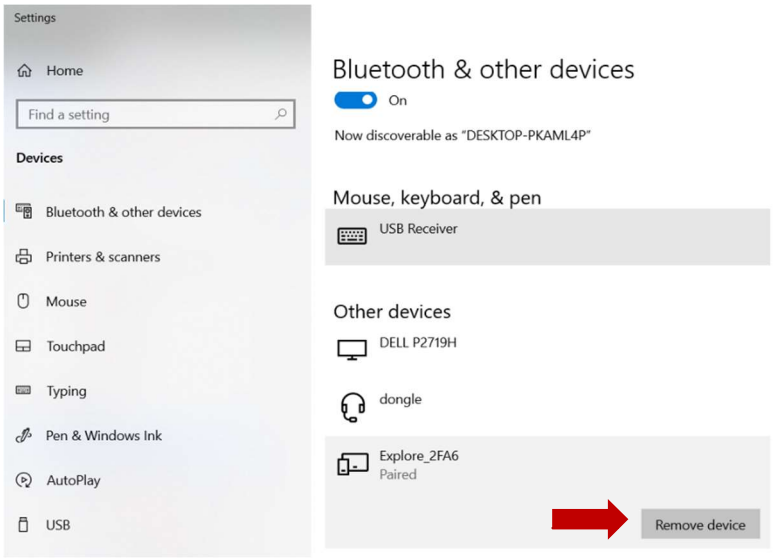


Your Explore should now be paired to the host machine. The connection can be established using the APIs (see section 3). Once the connection is active, wireless data transmission starts directly. Meanwhile, data is stored in the device memory simultaneously.

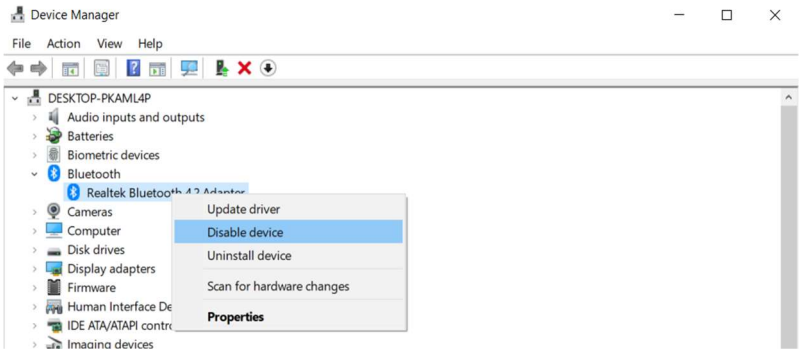
Bluetooth Dongle

A Bluetooth dongle may be helpful or even necessary if your host machine has not been equipped with Bluetooth, or if it is not working properly. Depending on your Bluetooth module and operating system, difficulties using all Bluetooth functionalities can occur. In this case, please notify our support. We can provide a Bluetooth dongle to help you maintain the desired mobility and flexibility. Here is an example of how to use a dongle on Windows:

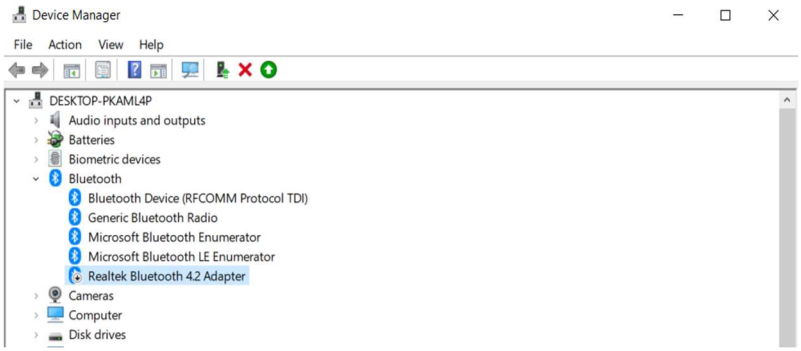
First, if you have paired an Explore device, remove it from the Bluetooth paired devices list before inserting the Bluetooth dongle.



Open the device manager and disable your Bluetooth adapter driver (do not "uninstall device").



Attach the Bluetooth dongle, update the device manager list, and the dongle should activate automatically.



Pair your Mentalab Explore device in the Bluetooth menu again, as described in the previous section.

Flash Memory

Mentalab Explore devices have an optional 512 MB of flash memory. The device starts recording data in the flash memory as soon as it is turned on (if no “memory full” error occurs). All data is saved into a binary file (.BIN) onto the flash memory. This file can be converted to BDF+ or CSV format with the help of the APIs.

A pink LED blinking at 2 Hz on startup means that there is not enough free space on the device memory for a long recording (440MB, enough for 8h recording at 500 sps). By pressing the button twice within three seconds after startup, the system starts deleting files, starting with the oldest one until it can allocate enough space. Then it starts recording normally.

Do not forget to retrieve the binary files from your device before deleting data. To do so, connect the device to a PC via a USB port. The device memory will show up as a drive in your OS, you can transfer the files to your computer as usual.

USB Connection

Always turn off the Mentalab Explore device before attaching it to a PC or charging. The device starts recording a file into the memory automatically after start-up. Attaching the device to a USB port without prior shut-down can terminate the recording session abruptly. If this happens, recorded data files can be incomplete, potentially causing a memory full error on the next run. If you need to save the recorded data, copy it via USB before freeing up space on the flash memory as explained above.

Connecting the device via micro-USB will reset the device. In case of a device freeze, please connect your device to a USB plug.

3.3 Device State Diagram

The following diagram gives an overview of the Explore device's behavior.

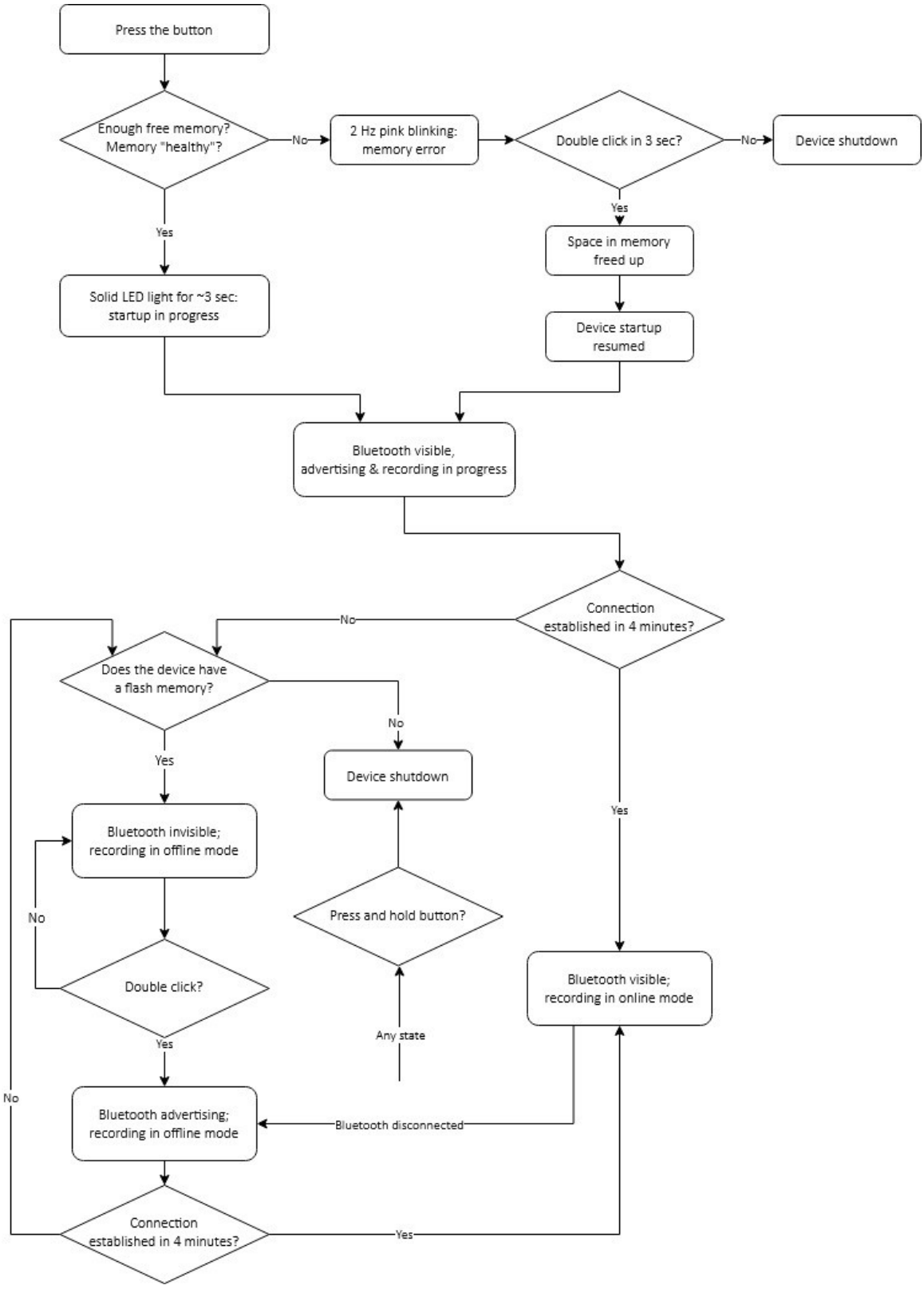


Figure 4. Explore device system states

3.4 LED Codes

LED Color	Blinking Pattern	Description
Red / Yellow / Green	At device startup, about 3 sec	Startup in progress. Green > 60 %, yellow 30 – 60 %, red < 30 % battery left.
Blue	Blinking 2x / sec	Bluetooth visible and advertising.
Blue	Blinking 1x / sec	Bluetooth visible and connected to the host machine. Online mode in progress.
Green	Blinking 1x / sec	Bluetooth is invisible; offline mode in progress.
Pink	Blinking 1x / sec, at device startup	“Not enough memory” error.
Pink	One-time flash	Button has been pressed; a marker with the timestamp corresponding to the button event is stored and transmitted.
Red	3x flash	Button has been pressed and held. The device will turn off.

3.5 Button Commands

Action	State	Effect
Pressing the button once	Device off	Device will turn on.
Double click	Memory full error, LED blinking in pink.	Frees up space on flash memory and returns to advertising mode.
Double click	Device in startup	Skips advertising and goes to the offline mode.
Double click	Device in offline mode	Starts advertising mode, device now visible via Bluetooth. Keeps recording on flash memory in parallel.
Single click	Device recording, online or offline	A marker is generated with a timestamp corresponding to the button event.
Press & hold	All states	Device will blink in red three times, terminate the recording session, and turn off.

3.6 Data Structure

Explore devices contain 4 or 8 channels of high-precision ExG sensors, 3 independent movement sensors (Accelerometer, Gyroscope, Magnetometer) and 2 environment sensors (Device Temperature, Battery level). The sensor data is always saved in the device's flash memory, while also being transmitted wirelessly when in online mode. Additionally, the device sends the following information to the host machine:

- A device information package including firmware version, ADC mask (active channels) and sampling rate.
- Markers (upon button push) which include the timestamp of button push and a code from 0 to 7. This code is generated by a counter in the MCU and each button press will increase this number by one. When it reaches 7, the counter will be reset to 0. This code can be used to distinguish it from digital markers (digital markers have a code larger than 7) and to detect missed marker packets, since two consecutive markers should have consecutive codes.
- Timestamps: The host machine can send a packet to Explore to synchronize the device with it or to indicate the timepoint at which the recording has started on the Explore device. The value in the host timestamp field of the mentioned packet contains the host timestamp based on the UTP protocol. Once you connect to the device via Bluetooth, this packet will be transmitted to the device automatically. Based on the time the packet has been sent and the internal clock timer of the device, the name of the current recording will be updated to contain a time tag associated with the start of recording (e.g. DATAxxx_01Jan2020_16h53m.BIN). If the recording is done completely in offline mode without any Bluetooth connection, its time tag field in the device name will contain dummy values (e.g. DATAxxx_ddmmmyyyy_xxhxx.BIN).

4 APIs

To use the device in online mode, configure its settings or convert offline data, we recommend using our main API, Explorepy for Python, which can be integrated into your desired application. Real-time impedance measurement, remote data recording and browser-based data visualization are some of the key features you can access with it.

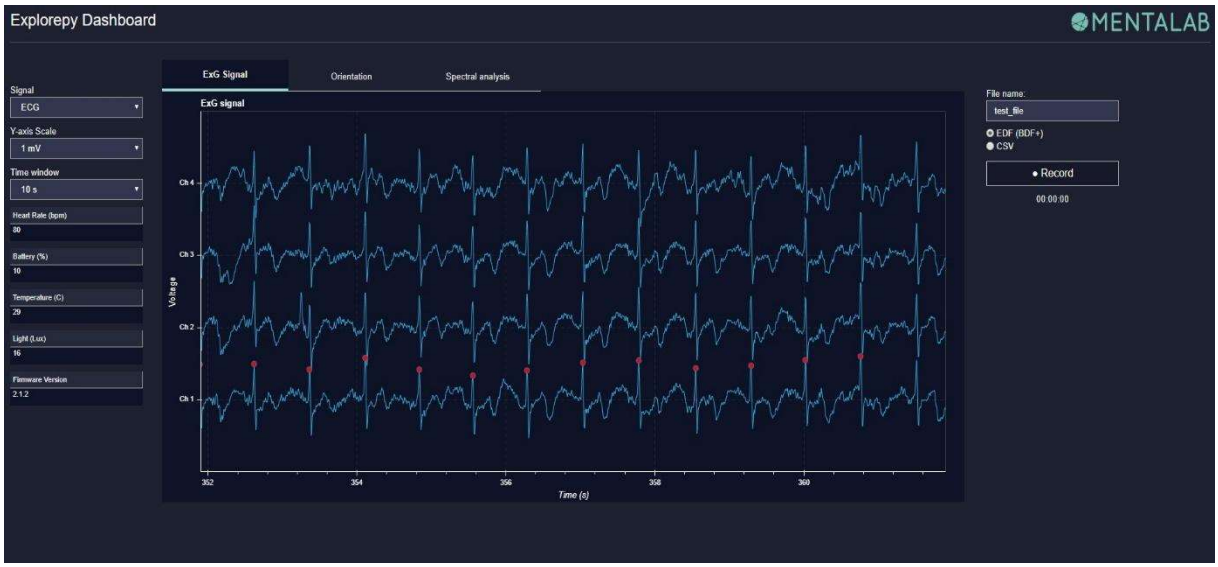


Figure 5. Browser-based dashboard for visualization of ECG data.

Please refer to the online documentation for the installation of Explorepy and its dependencies, as well as a comprehensive description of the functionalities:
https://explorepy.readthedocs.io

If you prefer to work with C++ or MATLAB, you will find the documentation for these APIs - LibExploreCpp (C++) and ExploreMATLAB - on our GitHub page. Note, however, that these APIs were built for earlier firmware versions and are not yet up to date, so make sure your device has the firmware version corresponding to the API you are using.

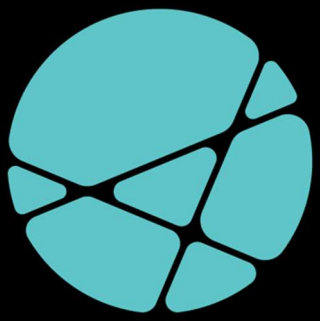
All Mentalab's application-sided code is open, so we invite you to use it and contribute to its development. The three APIs can be found on GitHub:
https://github.com/Mentalab-hub/

5 Device Troubleshooting

No.	Error	Cause	Solution
TD-1	When I turn on the Explore device, it blinks in a pink light and then turns off automatically.	At the startup, Explore checks if there is enough space on flash to record data for 8 hours. If not, it will blink in pink to show memory full condition.	To free-up space on flash memory, you can press the Explore's button twice while the pink light is blinking. This should be done within 3 seconds, otherwise the device will shut down automatically. The 3 seconds time constraint is for the purpose of avoiding unintended data loss.
TD-2	The size of the created file on the flash memory is inconsistent with the duration of recording.	Explore secures enough space for 8 hours of recording by allocating it at the beginning of a recording session. At the end of the recording session, the unused space will be deallocated. The user may interrupt this action by plugging the device in via USB while it is still operating, which blocks the device from deallocating properly and the user finds a file with a larger size than expected.	The data is safe, you can retrieve it as usual. Turn off the device and connect it to a PC, then copy the data from memory. Then turn the device off again, and if it blinks in pink, free up space as explained in #TD-1. Although not necessary, the user can format the memory as explained in the API documentations.
TD-3	Explore shows full memory while it should still have enough available space on flash memory.	As in #TD-2, this is likely caused by a corrupted data file which is larger than intended, because the device was plugged into a power source and forced to undergo a reset, terminating the recording and device operation.	Always turn the device off before attaching it to the USB or charging it.
TD-4	Explore has frozen, it does not respond to button presses.	Unexpected error or hardware damage.	Plug and unplug the device to USB. This will reset the hardware and the device will turn off afterwards. Turn on the device and it is ready to be used. If it does not solve the problem, please contact Mentalab's technical support.

TD-5	I cannot see the LED lights.	Either the device is out of battery, or the LED is damaged / an unexpected error has occurred.	Charge and reset the device by plugging it to a USB connection. If not resolved, contact us.
TD-6	Device is not discoverable, and it is emitting green light.	If not connected for a while or if has received a disconnect request from host machine, the device will go to offline mode.	Press the button twice like a double click. It will make the device visible again. The device should start blinking in blue at 1 Hz once successfully becoming visible again. You can now pair and connect to the device.
TD-7	Device cannot be connected and is emitting blue light.	Bluetooth error.	Turn the device off and on. Reset the program and see if the problem has been solved. If still not able to connect, unpair the device and pair it again.
TD-8	Signal is too noisy.	Bad electrode connection or Bluetooth interference.	Check if the electrodes are properly connected, especially the reference electrode. Make sure the cables are intact and correctly connected to the Explore, and that the impedance values are low enough. Else, try moving the Explore closer to the host machine, or turning off other Bluetooth devices nearby which may interfere.
TD-9	I observe a sinusoidal signal instead of applied signal.	Impedance mode is active.	Disable the impedance mode (e.g. with Ctrl+C) or simply restart the device to reset it to the default configuration.
TD-10	My device turns off after being disconnected for a while despite battery being fully or partially charged.	Record offline mode is meaningless for devices without flash memory. So, after being advertising for a while and not being able to connect, the device will turn off.	Explore advertises for 4 minutes after startup or if disconnected from a device and attempting to reconnect. Make sure to connect your device to a host machine within that time span.

TD-11	The recorded file's name does not have the correct time tag.	The host machine's date and time settings are incorrect.	The device receives this time tag from the host machine. It is likely that your system's date and time are not correct, especially if you use a dual boot system on your host machine.
TD-12	I have connected the device to the host machine, but the time tag of the recorded file on the device still contains dummy values (DATAxxx_ddmmmyyyy_xxhxx.BIN).	The Bluetooth connection was interrupted while transmitting this information, or the device has not turned off properly.	If the file created on the flash memory is partly corrupted, the device shut down incorrectly. Always turn off the device before plugging it to the USB. If the file is healthy, the Bluetooth connection has been interrupted: remove the source of electro-magnetic interference, e.g. electrical equipment or other wireless devices nearby.



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