EXO-H3

The Exo-H3 is the third version of Technaid's lower limbs robotic exoskeleton. On it we have put all our expertise and previous knowledge to bring you a **versatile, robust and reliable platform for your research**.

Exo-H3 can completely emulate the process of human walking replicating the previously introduced gait pattern through its six actuated joints in the sagittal plane. Thereby it can assist to people that have partially lost the capacity to walk after suffering a stroke, contributing to the current **neurorehabilitation research**.

The main advantage of the Exo-H3 is that, having been designed specifically for research, it allows the implementation of own algorithms as well as the application of different robotic control strategies. This, together with its ability to adapt to different sizes gives you a wide range of possibilities when carrying out your research.

For example, the Exo-H3 could be equipped with an **on-board computer** to interface between the internal Main Controller and a ROS (Robot Operating System) network.

In addition, the Exo-H3 also has an **Android App** as interface to operate the basic functions of the exoskeleton such us gait speed, motor assistance or stand up and sit down commands.

Calle Cabo de la Nao 2. Nave 12. Arganda del Rey, 28500, Madrid – España. Tel.: +34 918719974

www.technaid.com - info@technaid.com

Description of the Lower Limb Robotic System

This document gives a brief explanation about the main elements related to the EXO-H3 exoskeleton. EXO-H3 consists on:

1. Mechanical and electronic Parts.
2. H3 exoskeleton on ROS.
3. Control Android App.

Within Mechanical Parts we find motors, gears, extension bars, soles, hips attachment and straps. All these elements have been designed taking into account the knowledge generated through the previous versions of the exoskeleton. Exo-H3 is the best version we have made until today, with several mechanical as well as electronic improvements.

Regarding the Electronics, Exo-H3 includes three hardware developments: one **Main Controller**, six **Joint Controllers** and several **position, torque and pressure sensors** along the device. Thus, at the software layer, four **different communication protocols** allow us to control the device and obtain information from the sensors in real-time

The Main Controller was designed specifically for **real-time control** of the whole exoskeleton. It interacts with the Joint Controllers by acquiring sensory information and controlling the actuators. Its **small size and its very low power consumption** allows it to be placed on the exoskeleton structure minimizing connections, reducing the bulk, and the complexity and difficulty of wiring

The Main Controller has two independent CAN transceiver channels (one for each leg) used to connect with all the six exoskeleton's joints. This physical communication network guarantees **strict determinism, data collision avoidance and optimized data transfer** for small data packets.

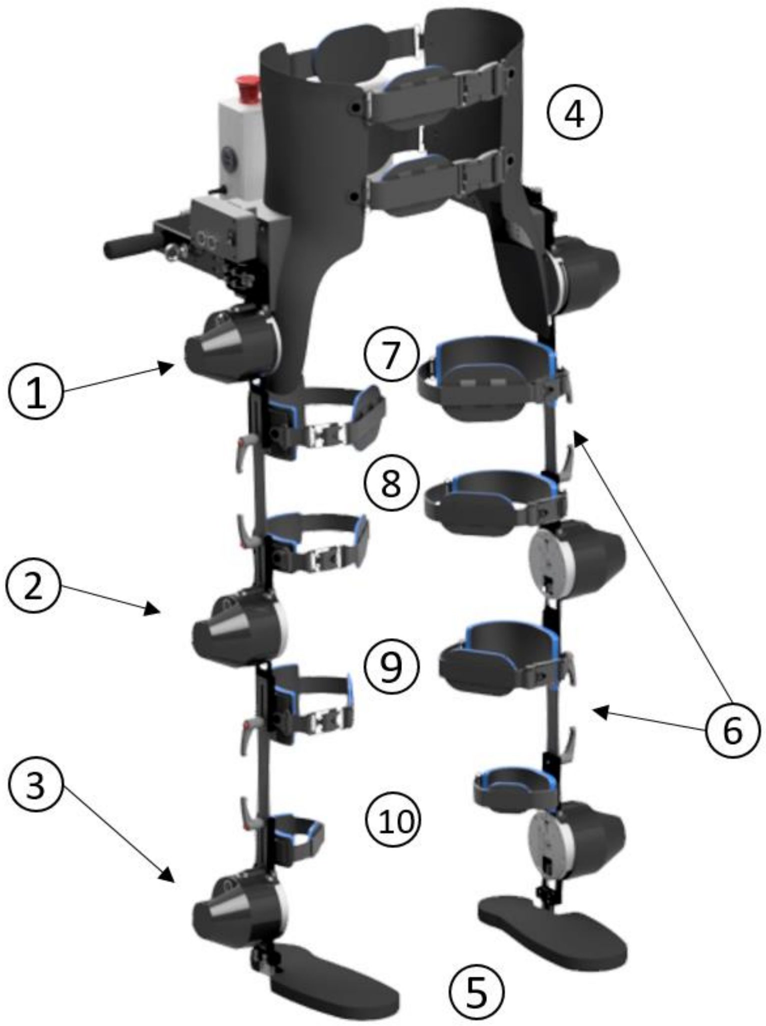
Joint Controllers and Main Controller communication cycles occur at a fixed rate (1 kHz). Besides, it provides built-in network error detection because at every message received, each joint has to return data information. In this way, the Main Controller has a strong way to determine the integrity of the network.

Regarding the wireless communications ports, a Bluetooth module to connect to the UI on a smartphone, a Wi-Fi module to collect all data generated by the exoskeleton, and a 2.4 GHz transceiver with proprietary protocol designed to interact with other hardware devices in the environment, are available

As the fourth communication protocol, the exoskeleton has a CAN Communication Protocol which is managed directly by the Main Controller and allows the wired communication with external devices in real time. This communication is compatible with several platforms as **ROS, Matlab** ® or **LabView** ®**.** The Exo-H3's open architecture allows an on-board computer, as an optional function required by user, which serves as an interface between the Main Controller (CAN protocol) and a ROS network (Ethernet, Wi-Fi).

In addition to wired communication with compatible platforms, Exo-H3 comes with a Control App designed for Android devices. This app provides a simple control of the system that allows to enter the walk, stop, sit down and stand up orders, among others.

Exo-H3 Mechanical Parts Description (1/2)

Exoskeleton	Mechanical parts
	1. Hip joint 2. Knee joint 3. Ankle joint 4. Hip strap 5. Insoles 6. Connecting extension bars 7. Thigh straps 8. Upper knee straps 9. Lower knee straps 10. Shank straps

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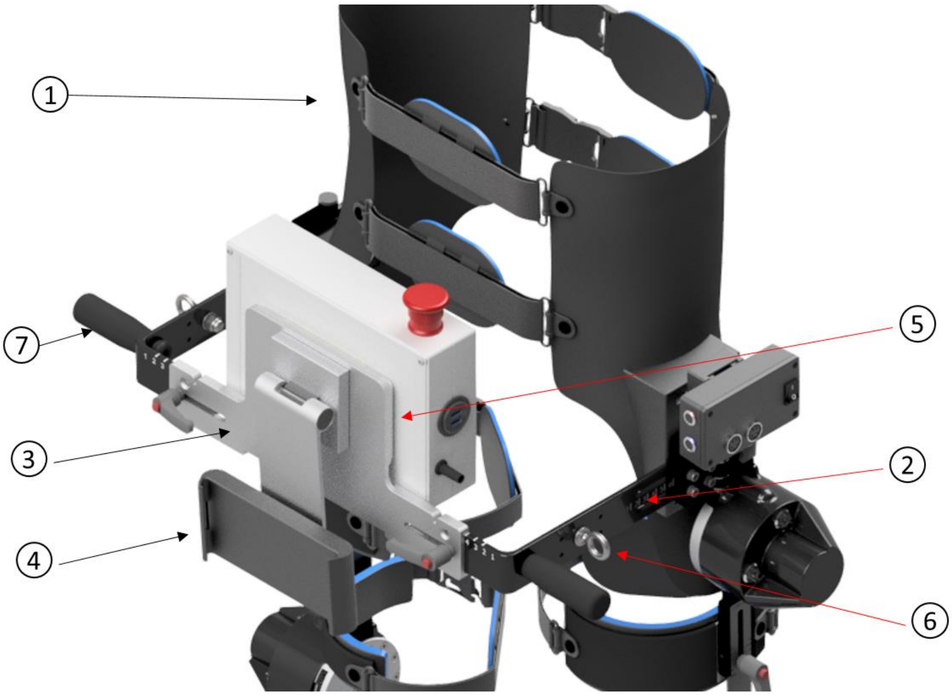
Exo-H3 Mechanical Parts Description (2/2)

Location of the main hip orthosis elements



Description of the elements

1. Hip orthosis	5. Battery adaptor
2. Hip strap side bars	6. Hoist eye bolt
3. Hip strap rear bar	7. Handlebar grip
4. Tablet holder (optional)	

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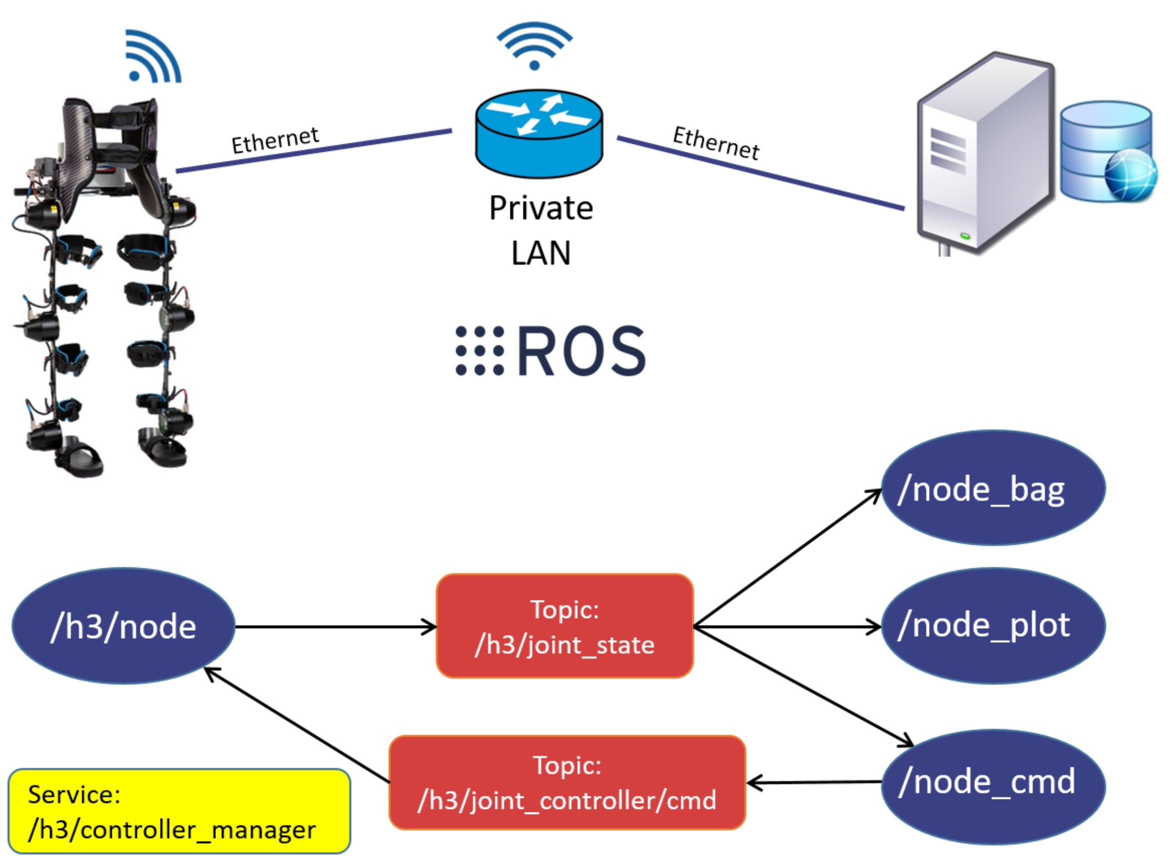
Exo-H3 on ROS

The Exo-H3 could be equipped with an **on-board computer** to interface between the internal Main Controller and a ROS network. When that happens, information regarding sensors will always be published to ROS topic. The Exo-H3 sets the internal controller reference signal by subscribing to a topic. This way, device setup will be handled through ROS services, e.g., to select controller, to set joint position limits, or to perform high-level tasks, etc.

Exo-H3 Connection to LAN through ROS

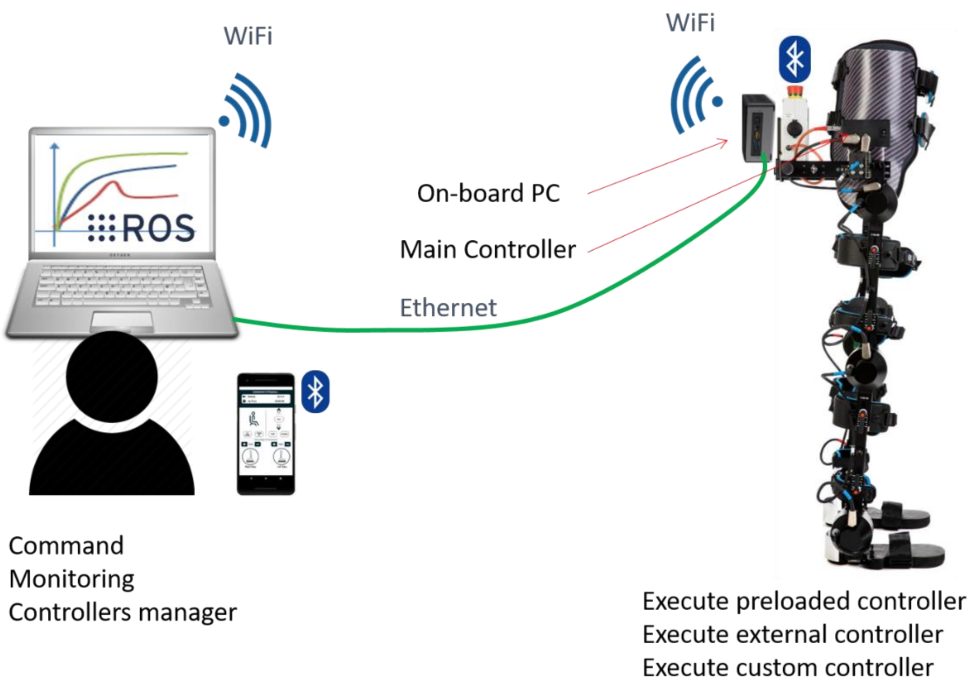


General connection between Exo-H3 and Local Area Network (LAN) to exchange information through ROS topics and services. Once the LAN connection is complete, the Exo-H3 becomes in a ROS node, publishing messages through ROS topic. Besides, the H3 will be able to subscribe to topics, receiving the reference signal of each joint controller. The connection to the LAN can be wired or wireless.

Capabilities:

Signal monitoring: Joint torque, joint position, Heel and Toe pressure, motor torque. Publishing on ROS topic.
High-level task control: Normal gait pattern (flat ground), sit down, stand up, right step, left step. Using ROS services.
Modify task parameters: Speed, assistance, passive/compliant. Using ROS services.
Medium-level control: with ROS topics, the set points are sent to the internal controllers: position controller, torque controller and stiffness controller.
Low-level control: tuning parameters of the internal PID parallel controller is allowed using ROS services.
Custom controller: Use the on-board computer for execute custom joint controller, create, load and execute your own controller over Exo-H3 capabilities using ROS libraries.
Joint-level controller: Independent joint controller set point is allowed.
Communication Interface: Use wireless (on-board PC Wi-Fi) or wired communication (External CAN bus, on-board PC Ethernet), you decide according with your requirements.
3D model for simulation: An Exo-H3 model suitable for joint-level controller simulation in ROS is available.

Exo-H3 Monitoring and control



General way to establish communication with the Exo-H3 control and monitoring. The Exo-H3 has available the internal controllers (position, torque, stiffness) and the option to develop your own controllers in the on-board computer.

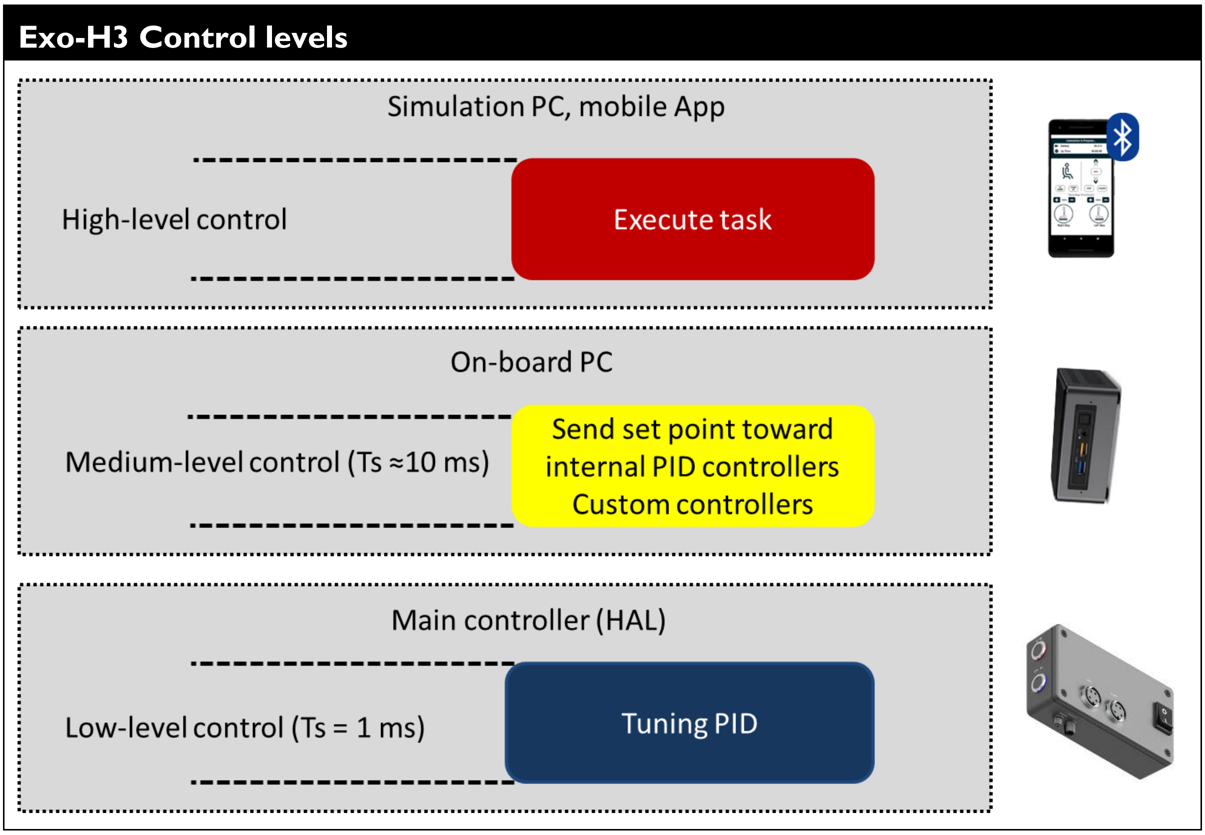
Exo-H3 Control Levels

The Exo-H3 has three types of internal controllers: position, stiffness and torque, which can receive reference signals from an external system. Besides, three control levels are available to implement control algorithms in the Exo-H3 using the existing controllers and others that can be implemented in the on-board computer, as shown in the picture below.

The low-level control has a sampling time of 1 ms, at this level it is allowed to tune the controllers by varying the controller parameters.

The medium-level control runs on the optional on-board computer with a current sampling time of 10 ms (this value can change depending on the computer). the output of a controller at this level will be the set point of an internal controller.

The high-level control (command) runs in a mobile application in Android operating system. The application communicates with the Exo-H3 via Bluetooth. At this level it is possible to perform internal tasks on the Exo-H3: normal gait pattern, standing up, sitting down, etc. This functionality can be used in ROS.

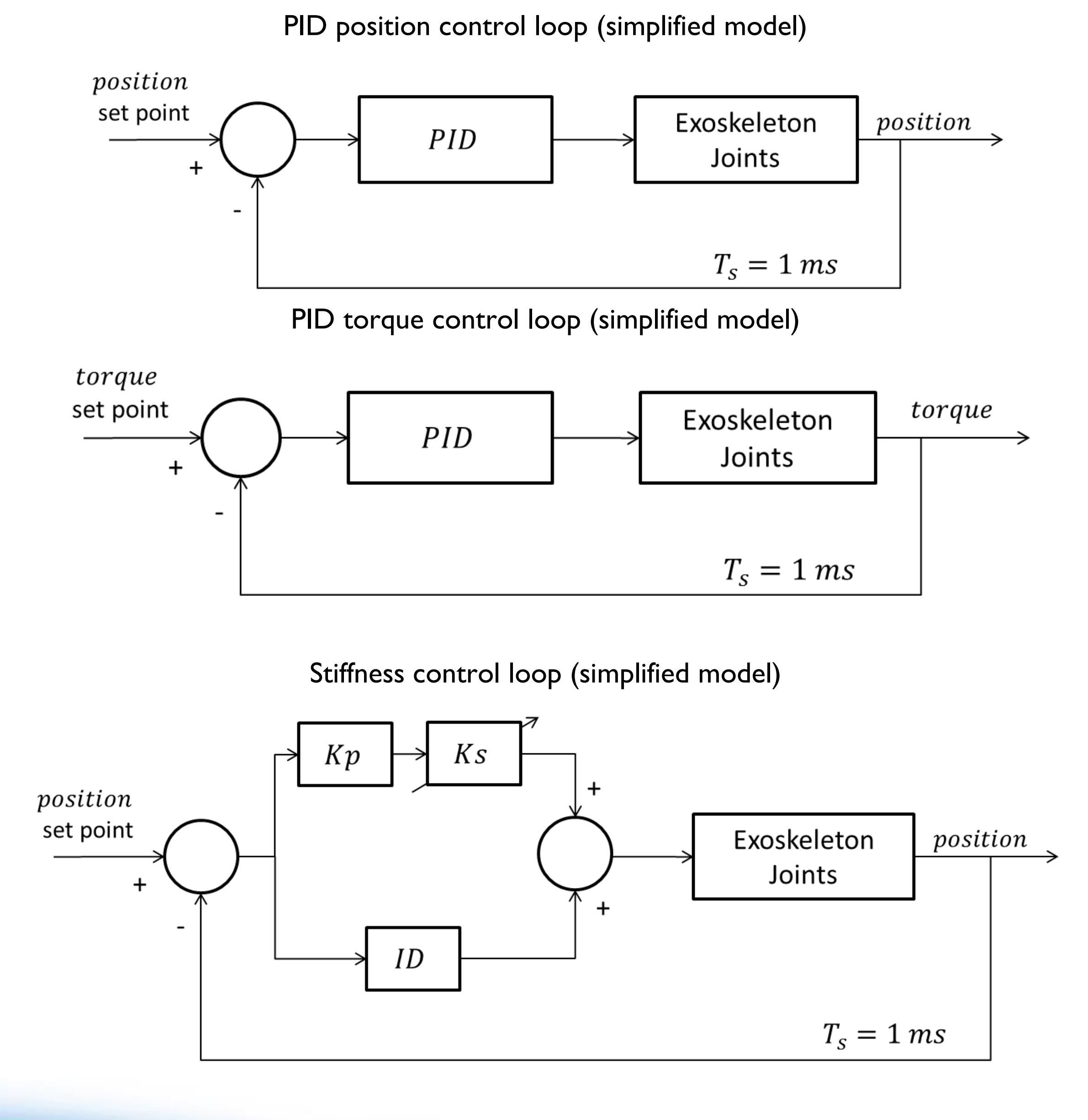


Exo-H3 Internal Controllers

The internal controllers in the H3 run inside the Main Controller at a 1 ms sampling time. The Main Controller sends the reading of the sensors and receives the set point of the internal controllers every 10 ms through the external CAN bus.

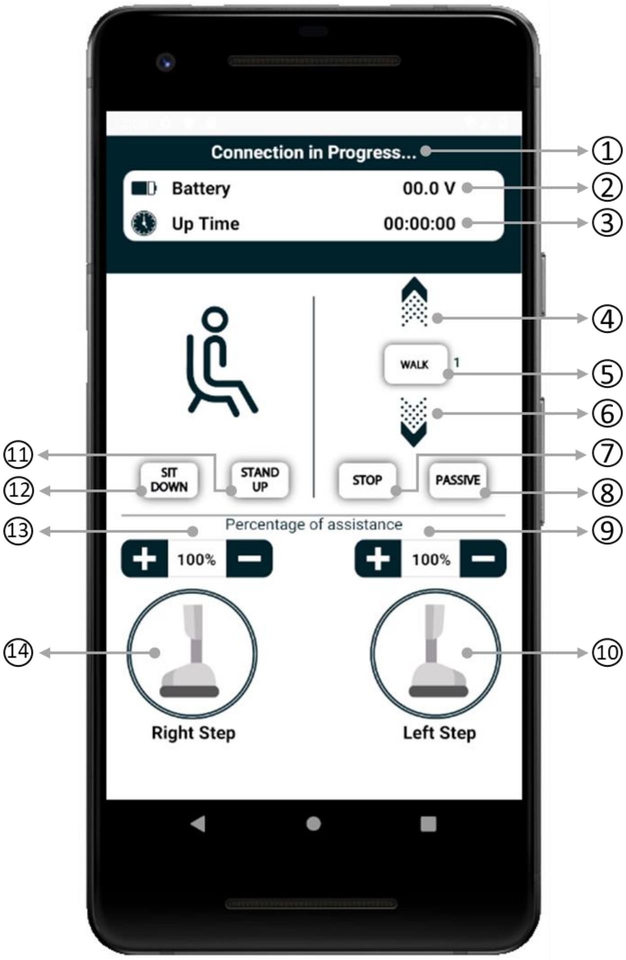
Interaction torque and position joints controllers are parallel PID controllers with tuning option. Stiffness control allows manipulate position controller gain.

Exo-H3 internal controllers



Control Android App

Buttons Layout



Operational Modes

1. **Process status:** Here is placed the current status of the device.
2. **Battery level:** Real-time value of the battery.
3. **Time Up:** It shows all the time elapsed since the device was turned on.
4. **Up velocity:** It allows to increase the speed of the gait.
5. **Walking:** Once the end-user and the user are ready to use the device, "Walk" bottom allows to start the operation with a preloaded gait pattern. By using the Up and Down arrows it is possible to increase or to decrease the speed of the gait (ten speed levels).
6. **Down velocity:** It allows to decrease the speed of the gait.
7. **Stop:** When the end-user is Walking with the device, the Stop bottom allows to finish the gait carrying out the whole gait pattern, and then the motors will be blocked.
8. **Passive/Complain:** The "Passive" bottom allows free engines movement with resistance; and the "Complain" bottom allows the same but very low resistance.
9. **Left Leg Assistance:** It is possible to set the assistance percentage, in the left leg, from 10% to 100%, increasing (+) or decreasing (-) in steps of 10%.
10. **Left Step:** It is possible to send independent step patterns for the left leg
11. **Stand Up:** When the device is completely placed, it is possible to enable this instruction. The end-user will feel assistance when rising.
12. **Sit Down:** Always the device has been placed on "stand" or "walking" mode, "stand to sit" is able to be used. The end-user will feel the device "brake", which slow down the end-user's movement onto the seat.
13. **Right Leg Assistance:** It is possible to set the assistance percentage, in the right leg, from 10% to 100%, increasing (+) or decreasing (-) in steps of 10%.
14. **Right Step:** It is possible to send independent step patterns for the right leg.

Exo-H3 Main Features

- Open Hips Attachment for an **easy installation**
- Easy **subject adaptation** through optional extended cables and extension bars (different sizes)
- Hips Attachment adjustable in the sagittal and frontal plane.
- **Toolkit** included.
- Two straps per segment to ensure an **optimal fixation**.
- Eye Bolts installed for **harness fixation**.
- Included **handlebars** to assist the gait.
- **Interchangeable battery** for a continuous use.
- Emergency stop.
- Communication **compatibility with several platforms** (Matlab ®, LabView ®, ROS, etc.)
- **Android App** for gait management
- Online support.

Exo-H3 Robotic System Technical Specifications

Number of Degrees of Freedom	6 degrees of freedom in the sagittal plane. One for hip, knee and ankle in both right and left legs.		
Type of Control	Position, Torque and Admittance in real time control.		
Final Actuator	Net Torque	35	Nm.
	Peak Torque	152	Nm.
Communication	External CAN-Bus Wi-Fi 2.4 GHz IEEE 802.11 b/g/n Bluetooth v3.0 (Class 2) 2,4 GHz Transceiver		
Power supply (Charger)	100 – 240 V AC / 50-60 Hz (AC power line)		
Battery LiFePO4	Size (H)	19	cm.
	Size (W)	6	cm.
	Size (L)	24	cm.
	Normal capacity Type	10.8	Ah.
	Normal voltage	19.2	VDC.
	Normal Power	207.36	Wh.
	Standard discharge current	5 (const.)	A.
Principal structure production material	Stainless steel and high resistance aluminum (7075).		
Exoskeleton sensors	6x Joint Position. 6x Joint Interaction Torque 4x Pressure Sensor (heel and toe)		
Joints Range of Movement (Flexion/Extension)	Hip (135°)	105° (flex.)	30° (ext.)
	Knee (110°)	105° (flex.)	5° (ext.)
	Ankle (60°)	30° (flex.)	30° (ext.)
Size Adaptability	Min. subject's height (*)	110	cm.
	Max. subject's height (*)	210	cm.
	Min. subject's weight	40	Kg.
	Max. subject's weight	100	Kg.
Dimensions	From 90 cm. to 148 cm. tall (approx.)		
	46 cm. long (side view) / 37 cm. (side view) without battery		
	65 cm. wide (front view)		
Weight	17 kg. approx. / 14,6 kg. without battery		

* Some sizes options are only available through optional accessories.