DSI-24 USER MANUAL

Wearable Sensing

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1 Disclaimer

1. 1 Disclaimer

Wearable Sensing's DSI-24 system is an EEG system designed for use in scientific and engineering research environments. Wearable Sensing's DSI-24 system was designed, constructed, and tested for performance and safety. However, this is a research instrument, and Wearable Sensing makes no warranty concerning its safety. It should only be used by knowledgeable individuals at their own risk.

The Wearable Sensing DSI-24 system is not an FDA-approved medical device for use in medical diagnostic or therapeutic applications. Its sole purpose is to measure EEG signals. Any other information gathered from this device, either implied or otherwise, is not the intent purpose of this instrument and is therefore not the responsibility of Wearable Sensing or its subsidiaries. Any usage of this instrument except for the specific purpose outlined above is strictly prohibited and voids all Wearable Sensing assurances of the system's durability or functionality except those strictly expressed in the accompanying Operation Manual.

The specifications, information, and performance of the Wearable Sensing DSI-24 system may be changed without notice. Since the use of this information and the conditions in which the system is used are beyond the control of Wearable Sensing and its subsidiaries, it is the obligation of the customer and/or the equipment operator to determine the correct and safe selection and settings and conditions of use of the device. The DSI-24 system is provided on an "AS IS" basis. Wearable Sensing, INCLUDING ITS SUBSIDIARIES, DISCLAIMS ANY AND ALL WARRANTIES EXPRESSED, STATUTORY OR IMPLIED WITH RESPECT TO THE SYSTEM OR THE MATERIALS, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTIES OF MERCHANTABILITY, NON-INFRINGEMENT OR THIRD-PARTY RIGHTS AND FITNESS FOR A PARTICULAR PURPOSE.

1.4 Regulatory Statements

CE Mark Wearable Sensing, LLC's **DSI-24** is self-certified as conforming with the EU directive for CE mark as a Battery-operated EEG headset (non-medical). As of 2017, Wearable Sensing (San Diego, CA USA) declares that the DSI-24 conforms with the relevant Directives for, Electromagnetic Compatibility Directive (EMC), Low Voltage Directive (LVD), and The Restriction of Hazardous Substances Directive. The following harmonized standards were applied:

EMC: ETSI EN 301 489-1 (2011/09) V1.9.2 & ETSI EN 301 489-17 (2012/09) V2.2.1
LVD: EN 61010-1:201

FCC: The DSI-24 is **FCC certified** in accordance with FCC 47CFR Part 15 Subpart B, October 1, 2014
The DSI-24 incorporates the a pre-certified wireless transmission module:

FCC (USA): Contains Transmitter Module FCC ID: QOQWT12
Contains Transmitter Module IC: 5123A-BGTWT12A

Japan: Contains Transmitter Module WT12 that is type approved with identification code R 209- J00036
KCC (Korea): Contains Module WT12 that is KCC certified with number: KCC-CRM-BGT-WT12-A
Anatel (Brazil): Contains Module WT12 that has a valid radio type approval for Brazil based on the Anatel homologation with identification number of 01233-16-03402.
NCC (Taiwan): This product contains an RF module that is certified in Taiwan with NCC certification ID number CCAM15LP0950T9 "本產品包含一個ID號為CCAM15LP0950T9 的RF模組"

1.2 Statement of Environmental Use

The DSI-24 system is for indoor use, altitudes up to 2000 m, between 5°C to 40°C, a maximum relative humidity of 90% and a pollution degree of 2.

1.3 Required Batteries

Only NB-4L batteries that are UL and/or CE listed can be used in this system. You may contact Wearable Sensing to purchase a suitable replacement battery.

2 Dry Sensor Technology Introduction

2.1 Dry Sensor Overview

Conventional EEG systems require highly trained technicians to abrade the scalp and apply electrodes and conductive gels. The process is time consuming, irritating to users, and prone to noise and artifacts, thereby limiting the practical usability of EEG monitoring in applied environments. Wearable Sensing's dry electrode EEG sensors overcome this technical hurdle by eliminating the need for abrasive and conductive gels EEG and enabling rapid and minimally intrusive recordings in naturalistic environments.

This uniquely high fidelity yet practical EEG recording technology builds on dry electrode sensors developed by QUASAR under funding from DARPA, the Army, the Air Force, the NSF, and the NIH, and integrated into headset designs that allow use by minimally trained personnel without assistance. These dry sensors record high quality EEG through-hair without the need for skin preparation, neither abrasion, nor the use of conductive gels. (Figure 1) The unique high-fidelity capabilities of behind these dry sensors rely on several technological advances for their performance, including silver/silver chloride pinned electrode tips, ultra-high impedance amplifiers located immediately behind each electrode, patented hybrid resistive and capacitive circuit design, active cancellation of common mode electrical artifacts (such as triboelectric discharges or 60Hz mains) for reduction of artifacts and environmental noise, and a Faraday shield on each sensor to reduce sensitivity to electrostatic noise. Furthermore, the mechanical structure of the headset includes a patented nested design of spring-isolated pods that ensures electrode stability and motion isolation, allowing artifact free recordings during ambulation. In addition, the sensors can be individually manipulated to improve their contact with the scalp and easily adjusted fit to various size heads.

The main benefits of using Wearable Sensing's DSI Systems are as follows:

1. High-Fidelity Artifact-Resistant Dry Sensors
   - Sensors require no skin abrasion gels or fluids
   - High fidelity EEG signals without environmental noise
   - Sensors at the International 10/20 System
   - Spring loaded electrode tip allow painless contact and resistance to motion artifacts
2. Practical and Comfortable Headset
   - Rounded pin electrode tips that work through hair
   - Comfortable for long-term and repeated use
3. Rapid Set-Up
   - Headset typically self-donned in <3 minutes
   - Easy-to-use headset is instantly taken off
   - No need for washing head afterwards
4. Ambulatory System
   - Mechanical designs reduce motion artifacts
   - Integrated electronics
   - Bluetooth and USB data transmission

Figure 1: Wearable Sensing's Dry Sensor

2.2 Signal Quality

The signal quality recorded from these dry sensors is comparable to that obtained from wet electrodes attached by a technician. Error! Reference source not found. **and** show, respectively, overlays of c ontinuous alpha activity and of an auditory evoked potential, both recorded with juxtaposed wet and dry electrodes simultaneously; both recordings show similar EEG signal morphologies and exhibit > 90% correlation between signals from the wet and dry electrodes.

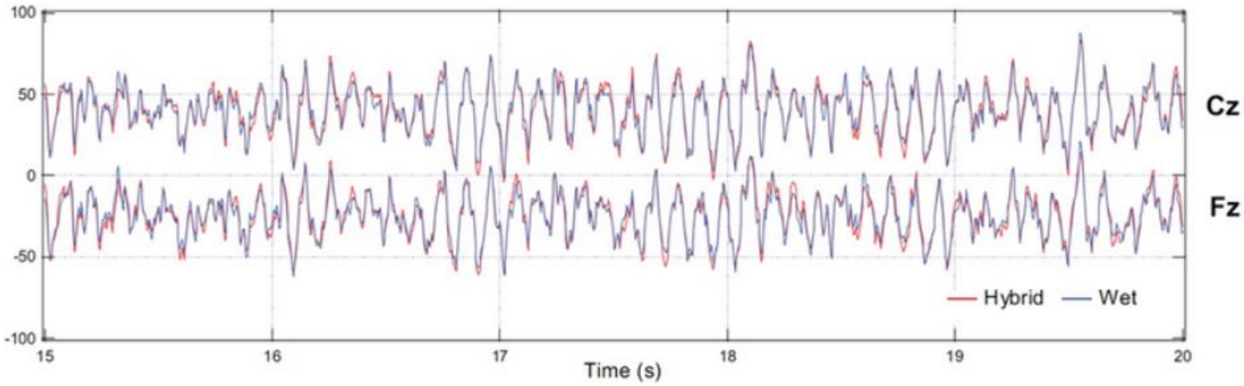


Figure 2: Signal quality comparison of simultaneous, side-by-side wet and dry electrodes

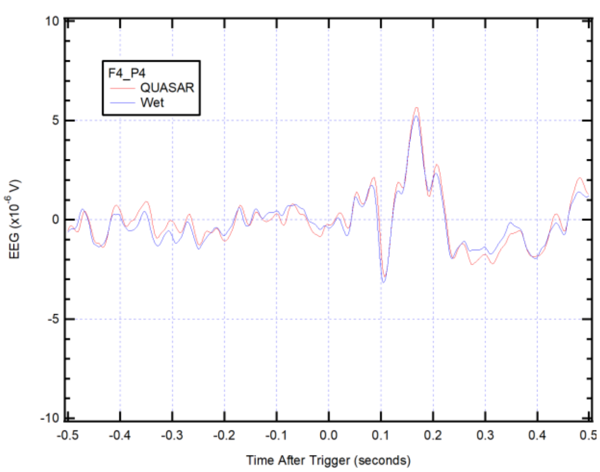


Figure 3: Signal quality comparison of simultaneous, side-by-side wet and dry electrodes during an Auditory Evoked Potential (N100-P200)

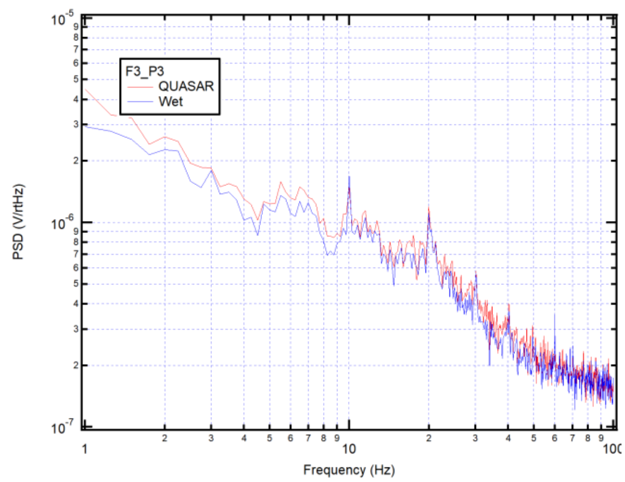


Figure 4: Signal quality comparison of simultaneous, side-by-side wet and dry electrodes during a Steady State Visually Evoked Potential (10 Hz); Dry electrode noise is higher at lower frequencies (not statistically significant)

Figure 4 shows a power spectrum of EEG signals recorded from wet and dry electrodes during generation of a steady state visually evoked potential from a 10Hz flickering stimulus. Both signals show comparable spectra with peaks at 10Hz and harmonics at 20Hz and 30Hz. It is also notable that the dry electrodes are more immune to 60Hz from the electrical mains than the wet electrodes due to both the wireless modality as well as the individual Faraday cages.

2.3 Electromagnetic Resistance

Despite the ultra-high impedance amplifiers and hybrid resistive and capacitive circuitry, dry electrodes can be susceptible to electromagnetic interference (EMI).

2.3.1 Faraday Cage

To prevent EMI pick-up from affecting the EEG signal, Wearable Sensing has enclosed each active electrode inside a Faraday cage in the form of a conductive outer enclosure and a ring of pins on each sensor. (Figure 5) This Faraday cage prevents external electrical activity from reaching the inner electrodes, thereby reducing EMI. The only signal that can therefore arrive to the active electrode is from the unprotected side, which is the scalp, and thus EEG.

Figure 5: Schematic of active dry electrode EEG sensor showing the electrode tip in yellow, the active electronics inside the red enclosure, the Faraday cage in grey sensor enclosure and green outer ring and back cover, and the inner spring in purple.

2.3.2 Common Mode Follower

While the Faraday cage protects from EMI coming from the outside, there are significant electric fields that can appear on the body and arrive to the electrode via skin conduction. These field can emanate from several sources: a) changes in the external free space, such as someone walking past you, b) triboelectric discharges, such as rubbing your feet on the floor when walking, c) changes in body shape, such as going from sitting to standing, or d) changes in resistive contact, such as grabbing a grounded object. These electrical fields can produce very large common voltages on the entire surface of the body including the scalp, hence called Common Mode (CM), which could intermix and mask EEG signal.

Wearable Sensing's systems protect against CM artifacts through its patented Common-Mode-Follower (CMF) technology. Physiological signals such as EEG, are typically measured as the potential difference (K1) in relation to the system ground, which has 2 components: the first is the very large common mode artifact on your body (K3) in relation to the system ground, the second is the very small EEG data that can be measured between sensors (K2). (Figure 6)

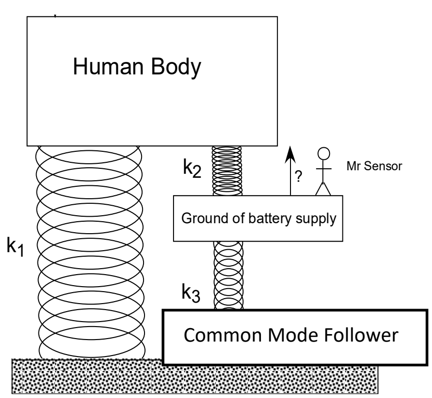


Figure 6: Illustration of electrical components of physiological measurement, where K1 is the electrical signal measured on the body in reference to the system ground, K2 is the common-mode signal measured in relation to the ground, which then serves as the EEG sensor's ground thus allowing high resolution measurement of the EEG signal without needing to digitize K1..

The CMF sensor measures the electrical potential on the body in reference to the system ground (K3), which can include mains frequency, triboelectric discharges, electromagnetic transmissions, as well as EEG, EOG, EMG signals. This CMF sensor is like the EEG sensors, except it has a wider bandwidth but lower gain. The CMF then acts as the ground of the EEG sensors, so that when we measure the difference between the sensors, we only have to digitize K2, and thus can use only a 16-bit digitizer instead of requiring a 24-bit digitizer.

An analogy to understanding the CMF is using a camera to measure the head movement of riders on a roller coaster. If the camera is on the ground videoing the riders, it has to measure a very large field of view at very high resolution to measure the riders' head movements. Alternatively, a lower resolution camera mounted on the roller coaster (i.e. "moving the ground" to the riders), could more accurately measure their head movements. (Figure 7)

A.

B.

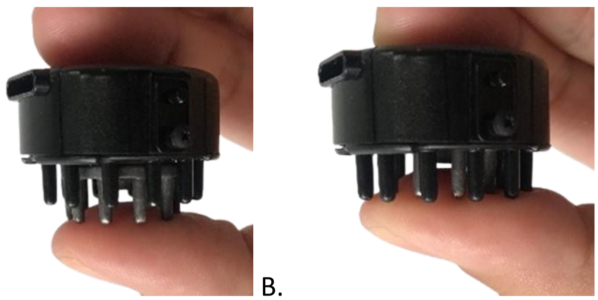

Figure 7: Common-Mode Follower (CMF) analogy: to measure head movement on a roller coaster with A) a ground-based camera would require a very high-resolution camera, or B) mounting a lower resolution camera on the coaster.

This works very well to eliminate CM artifacts without any signal distortion as all the sensors all have very good gain and phase matching, so that any common signals are canceled by the referencing, which is essentially a measure of the difference between any two sensors' potential. Here's a simple explanation of referencing: EEG is the potential difference between two points on the head. Our system is referential, which means that all the sensors are referenced to the location of the CMF, which by default is Pz on the DSI-24. So, when we digitize "F3", that is really F3-Pz, and F4 is F4-Pz. So, if we want F3-F4 = (F3-Pz) - (F4-Pz), the Pz cancels out arithmetically.

2.4 Motion Artifact Resistance

EEG systems typically suffer from susceptibility to motion artifacts due to passive electrode designs, which allow cables to pick up electromagnetic interference capacitively when moving through the air. Dry electrodes further suffer from increased risk of sliding on the scalp due to a lack of gel which would allow the connection between scalp and electrode to remain intact even if the electrode is shifted.

To combat this challenge, Wearable Sensing 's dry sensors include an amplifier right behind the elecrode tip, which amplify the high impedance signal inside the Faraday cage, and pass to the digitizer through low impedance cables, thus reducing EMI pick up by the cables. In addition, each sensor has a spring that can absorb motion both vertically and horizontally. (Figure 8) When the head moves, that relative motion of the headset due to inertia is absorbed in all directions by the spring, allowing the electrode tips to remain in constant contact with the scalp, avoiding motion artifacts in the acquired signal.



A. B.

Figure 8. Photo of sensor with A) relaxed internal spring and B) activated inner spring, showing grey inner electrode becoming flush with the black outer ring of electrode tips.

The headsets have additional levels of spring mechanical isolation and tightening that provide further protection against motion artifacts.

These approaches allow wearers to move freely in a real-world environment with a high degree of EMI and motion artifact resistance. Of course, there are limits to this protection, and currently, users can walk, and move as they would usually do in a daily work environment, but running or jumping are likely to introduce some transient artifacts in the EEG signal (see Section 05.12 - Motion Artifacts), however, as soon as these vigorous motions are halted the signals are clean again, unless the subject is now sweating (see Section 5.10 - Sweat Artifacts)

Furthermore, these mechanical designs in the sensors and headset have been carefully tuned with user comfort in mind so that the downwards force holding the sensors against the scalp provides adequate contact pressure for good signal quality while remaining within comfortable limits for long-term wear.

3 System Overview

3.1 DSI-24 Overview

Wearable Sensing's DSI-24 EEG system is designed for easy and comfortable measurement of high-fidelity EEG signals in a laboratory environment and relaying the EEG data to an external PC. Data is transmitted either via Bluetooth® or a wired micro-USB cable to a PC. Some DSI-24 systems also include Internal Memory (up to 60 hours continuous recording).

The EEG sensors for the DSI-24 system are mounted in a lightweight, user-adjustable headset, which positions the sensors at the nominal Fp1, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, P4, T6, O1 and O2 positions of the International 10/20 System. The DSI-24 system also measures from two earclip sensors placed on the earlobes (A1, A2). A reference sensor (Common Mode Follower, CMF) is placed at the nominal Pz position.

Figure 9: Donned DSI-24

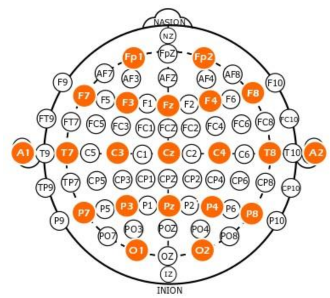


Figure 10: DSI-24 Sensor Locations using the International 10-20 System

Uncompromising Signal Quality

- Active dry electrode sensors with 2-stage amplification and digitization in headset
- Research-grade EEG signal (>90% correlation with wet electrodes)
- Patented artifact-resistant electro-mechanical designs suitable for ambulation in naturalistic environments
- Continuous impedance monitoring

Practical EEG

- Fully integrated, complete EEG system in a single wearable device
- Rapid set-up (<5 min) and clean up (<1 min)
- Adjustable to fit a wide range of head sizes
- Comfortable for continuous and repeated long-term use

Powerful Options

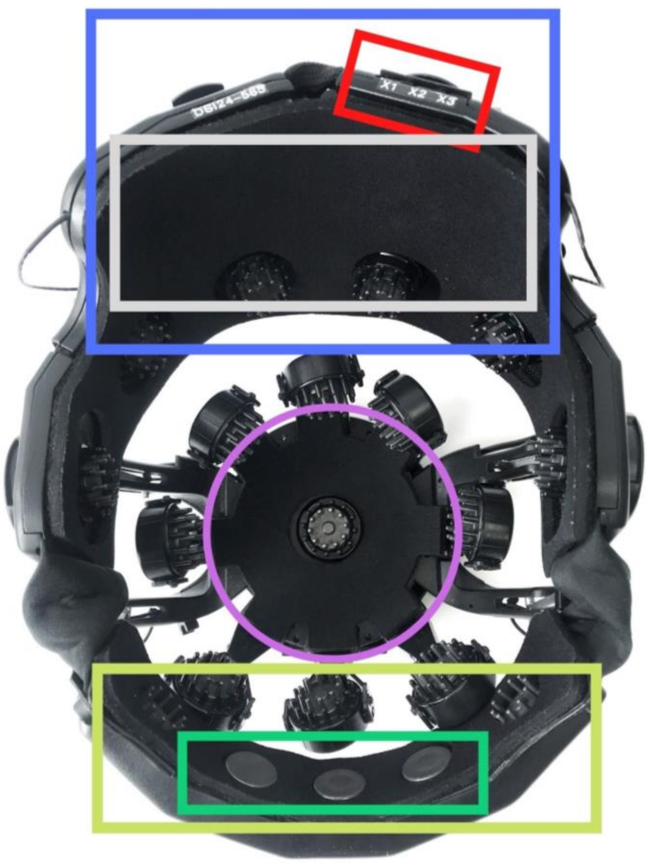
- Headset can be used with or Without VR.
- Wireless triggering for synchronization of multiple devices for hyper scanning or Evoked Response Potentials (ERPs)
- Bluetooth or wired-USB transmission
- Optional embedded 3D accelerometers

Intuitive Software Included

- DSI-Streamer: Signal quality metrics, ERPs, EDF and CSV data output file formats (raw and filtered)
- API for Windows/Mac/Linux/ARM
- Real-time data streaming: LSL, TCP/IP

The various parts of the DSI-24 are shown in the following photos.

SENSOR ARM
REAR ADJUSTMENT KNOB
EARCLIP SENSORS
BATTERY COMPARTMENTS
FAST USB PORT
TRIGGER INPUT CONNECTOR



FLAT FOREHEAD ELECTRODES
EXG INPUT PORTS
BACK PIECE
CROWN FOAM PAD
FOREHEAD STRAP FOAM PAD
BACK PIECE FOAM PAD

TOP HUB
CONTROL PANEL
FOREHEAD STRAP
TOP HUB ADJUSTMENT ELASTICS
MICRO-USB PORT

3.2 System Components

The DSI-24 EEG system is supplied in a single carry-case. The ancillary components are in two layers, as illustrated in the photographs below.

<table>
<tr><td colspan="2">Top Layer
</td><td colspan="2">DSI-24 Headset
</td></tr>
<tr><td>Measuring Tape
</td><td>Compact Mirror
</td><td>Utility Tool x 2
</td><td>Cleaning Solution (70% Isopropyl Alcohol)
</td></tr>
<tr><td>Battery-operated Cleaning Brush
</td><td>Li ion batteries (NB-4L, 3.7 V) x 2
</td><td>USB Bluetooth Adapter
</td><td>USB drive with DSI-Streamer, Bluetooth drivers & User Manuals (PDF)
</td></tr>
</table>

Bottom Layer	*Battery Charger*
	

*Fast USB cable (USB/2.5mm jack) *included in systems with Internal Memory*	*Micro-USB cable (USB/2.5mm jack) For WIRED Communication*	*Spare Rear Foam Pad*	*Spare Inner Foam Pad*
			

3 ft USB Male to Female Extension Cord For Bluetooth Dongle	*Spare Forehead Strap Foam Pad*	*Spare Inner Electrodes **x 17***	*Spare Snap Electrodes **x 2***	*Spare Flat Electrodes **x 3***
				

3.3 Auxiliary Sensors

Wearable Sensing has several types of auxiliary sensors that augment the measurement capabilities for the DSI-24 EEG system. These include ExG (EEG, EOG, EMG, or ECG) sensors, Galvanic Skin Response (GSR), respiration, and skin temperature sensors. Up to 3 of the sensor configurations can be plugged into the 3 external auxiliary input ports on the DSI-24 headset at one time.

There are several ExG configurations of sensors that can be plugged into the DSI-24's auxiliary ports:

(R) Referential – for use as single sensor configuration, and would be referenced in relation to the system's hardware reference (Pz), or re-referenced in software

(D) Differential– for use as a dual sensor for differential measurements, which are measured as a potential difference between each other, and are thus not related to the system's reference. This is often used for ECG, EMG, HEOG, VEOG measurements.

(L) Linked – for use with dual sensor configurations, where the digitized signal is the average of the measurement from both sensors in reference to the system's analog reference (typically at Pz). This is typically used for linked-ear or linked-mastoid reference measurements. In the DSI-24, the earclip sensors are digitized individually, and their average is calculated in software.

Electromyogram (EMG) -
measures electrical activity in response to a nerve's stimulation of the muscle

Electrocardiogram (ECG) -
measures heart's rhythm and electrical activity by detecting electrical signals produced by your heart each time it beats

Electrooculogram (EOG) –
can be used to measure vertical and horizontal EOG vectors

There are a few physiological sensors offered by Wearable Sensing. Photos of them are below:

Galvanic Skin Response (GSR) Sensor
measures changes in sweat gland activity that are reflective of the intensity of our emotional state, otherwise known as emotional arousal

Respiration Sensor Belt
measures respiration rates of subject

Skin Temperature Sensors
measures subjects' skin temperature

4 Using the System

4.1 Operation

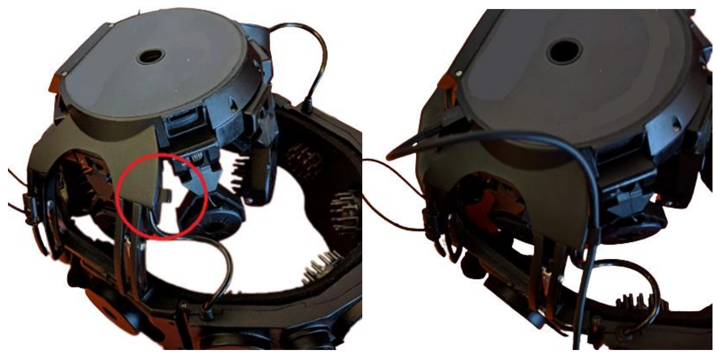
4.1.1 Buttons

The DSI-24 System has 2 buttons and 4 LEDs with their functionality shown below:

FUNCTION	ACTION REQUIRED	LED RESPONSE	STATE
To turn headset on	Double Press POWER	STATUS 2X	HEADSET ON
		BATTERY 1X	HEADSET ON
To turn headset off	Press & Hold POWER	STATUS FLASHING + ERROR FLASHING	HEADSET OFF
To see power status	Single Press STATUS	NO LED RESPONSE	HEADSET OFF
		STATUS 2X	HEADSET ON
To see battery charge status	Single Press STATUS	BATTERY 1X	>95% BATTERY
		BATTERY 1X + BATTERY 1X	30-95% BATTERY
		BATTERY 1X	10-30% BATTERY
		BATTERY FLASHING	<30% BATTERY
Analog reset for amplifiers	Single Press STATUS	STATUS 1X	DAQ OFF
		STATUS 2X	DAQ ON
Low battery warning	-	ERROR 1X	Low battery warning
Unexpected alarm	-	ERROR 1X	Unexpected alarm, if persists, call support
Error Alarm	-	ERROR Continuous	System Error; restart system, if persists call support

4.1.2 Wired Cable and Driver

If using the headset in **WIRED MODE**, connect the headset to the PC and turn the headset on.

STEP 1 Connect the micro-USB cable to the DSI-24 by plugging the micro-USB end into the crown piece and the USB end into the PC you are using.	
STEP 2 There is a <u>strain relief bracket</u> on the back arm of the headset. Attach the USB cable into the bracket to hold the cable in place.	
STEP 3 Press the **POWER** button twice on the front panel within 2 seconds to turn on DSI-24 system. The Green LED will flash twice to indicate that the system is turned on. One or more of the battery LEDs will light up indicating the current battery level.	

- Before attempting to make connection the first time, install the Silicon Laboratories driver included on the USB memory drive supplied with the headset.
  - Refer to the DSI-Streamer Software User Manual for further instructions.
- Each time thereafter, you must identify the communications ports used by the DSI-24 system.
  - Refer to the DSI-Streamer Software User Manual for further instructions.
- You can also watch the following video for a step-by-step tutorial for how to set up the DSI-24 in wired mode: https://youtu.be/B-sn_LRXB7A?t=316

4.1.3 Wireless Dongle and Driver

If using the headset in **WIRELESS MODE**, pair the headset to the PC using the USB-Bluetooth adapter and turn the headset on.

STEP 1 Plug the USB-Bluetooth dongle into the 3 ft extension cable. Plug the extension cable into the PC. Doing this will both optimize transmission range as well as avoid signals being blocked by the PC. ○ It is recommended to use the supplied SENA 100 USB Bluetooth receivers to ensure smooth connection between the headset and PC. ○ The first time a SENA Bluetooth module is plugged in to the computer, you will need to install the drivers for the Bluetooth device. ○ Please refer to the WS_Parani-UD100_Bluetooth Support v1.0.5 that is located in the provided USB Key ○ Or you can watch the following video for a step-by-step tutorial on downloading the Bluetooth Driver: https://youtu.be/B-sn_LRXB7A?t=151	
STEP 2 Press the POWER button twice on the front panel within 2 seconds to turn on DSI-24 system & seek Bluetooth connection. ○ The Green LED will flash to indicate system power. ○ One or more of the battery LEDs will light up indicating the current battery level, ○ The Green Status LED will start to flash indicating that the headset is looking to connect.	

4.1.4 On-Board Storage (Optional Feature)

DSI systems can be outfitted with internal data storage which allows recording of up to 60 hours of data while away from a PC.

Headset donning and set-up requires a PC being used in wired or wireless modes, after which users can then walk away from the PC and continue to record data directly on the headset.

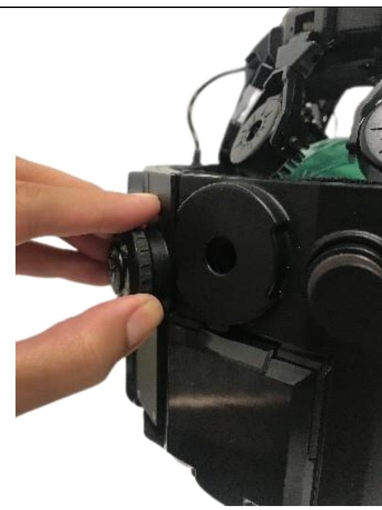
At the end of recording, data download can then be quickly accomplished via a special fast-USB connection to the PC.

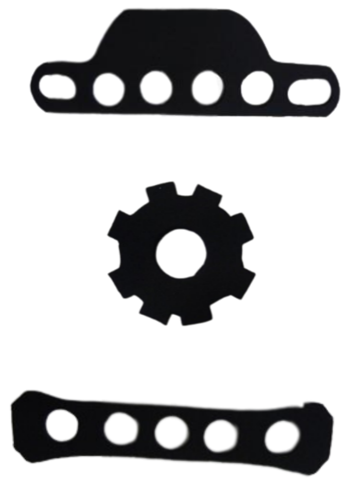
Storage can be installed at time of manufacture or after purchase but may require shipping headset back to manufacturer.

- Refer to the DSI-Streamer Software User Manual for further instructions.

4.2 Putting on the DSI-24

The steps below are a comprehensive overview on how to properly don the DSI-24. You are also welcome to watch our DSI-24 Video Donning Tutorial here: https://youtu.be/n59Uj_rQAjg

STEP 1 **VISUALLY INSPECT THE HEADSET** *Before beginning the donning process, visually inspect the headset and assess cleanliness and for any broken or damaged parts. In practice, cleaning should be performed after each use.*	**Visually inspect** the electrode tips for signs of abnormal wear/tear, damage, or breakage. ○ See **section 6.3** on Replacing Electrode Tips for when and how to replace electrodes in poor condition. Electrode tips are coated in Ag/AgCl. As they wear, the Cl wears off, exposing the Ag, leaving them shiny ○ Top electrode is in good condition (not shiny) ○ Bottom electrode is in poor condition (shiny)	 
	Test **the rear adjustment knob** by pulling it straight out, pulling on the front band to loosen it, then pushing the knob straight in, and turning it clockwise to ensure that it is tightening the cord/front band accordingly. Test that **T3 and T4** are sliding from left to right (listening for the “click” of the plastic at each interval), and that the elastic cords around T3/T4 are not frayed.	

	Ensure that the **sensor arms** can hinge up and down smoothly and with consistent force.	
	Inspect all **interior foam pad**s for cleanliness and security to the Velcro	
	Inspect **the earclip sensors**, making sure that the cable is not damaged and that the clip is working properly.	

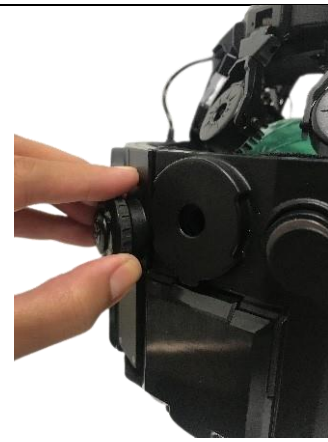
	Place the **charged batteries** in the battery compartments on the back of the headset	

STEP 2 **MEASURE HEAD CIRCUMFERENCE**	Measure the head circumference by running a tape measure from the nasion (the point in between the eyebrows, where the forehead meets the nose), passing above where the ears meet the scalp, and to the inion (the projecting part of the occipital bone at the base of the skull. o The DSI-24 has been designed for the head circumference range of 52-62 cm. Within this range, the headset will position the electrodes within ~1.5 cm from their exact locations according to the International 10/20 System. o For heads ranging between 52-54 cm, the headset may be a bit loose, making F7/F8 and T5/T6 more susceptible to motion artifacts. o For heads sized >62 cm, the DSI-24 may still be used, however, may cause slight discomfort and/or yield electrode locations further from their target locations according to the International 10/20 System.	

	If applicable, subjects may keep their eyeglasses on during the donning or put them on after the donning has been completed.	

STEP 3 **SCALP ASSESSMENT**	Assess the subject's scalp for the following items: o Dampness: Subjects should thoroughly dry their hair before donning any DSI system o Lice: Refer to **section 8.2** on lice for further information o Abrasion, pimples, cuts/open sores, etc.: Refer to **section 8.3** on scalp injuries for further information o Hair products: It is recommended that subjects wash their hair with a mild shampoo the night before. Refer to **section 8.4** on hair products for further information.	
	Assess the subject's hair type. The headset should work on most hair types, however, we do not recommend using DSI systems on braided or dreaded hair. If the subject has long and/or thick hair, complete the following steps before donning the headset to help the sensors go through the hair: o Remove all hair clips, elastics, etc. and allow the hair to fall straight down along the direction of growth. o Expose the subject's ears by parting the hair from above the ears, splitting the hair along the vertical line created from the shoulder to the ear.	

<table>
<tr>
<td rowspan="3">STEP 4

PREPARE THE HEADSET</td>
<td>Loosen the headset adjustments by pulling the rear adjustment knob directly out and pulling the forehead strap forward, expanding the headset circumference.</td>
<td></td>
</tr>
<tr>
<td>Release the cord locks on the sides of the headset and pull the top hub directly up to completely loosen the cords.</td>
<td></td>
</tr>
<tr>
<td>To turn on the headset, press the POWER button twice (within two seconds).

o The green LED light will start to flash consistently indicating that the DSI-24 is turned on and in pairing mode</td>
<td>
</td>
</tr>
</table>

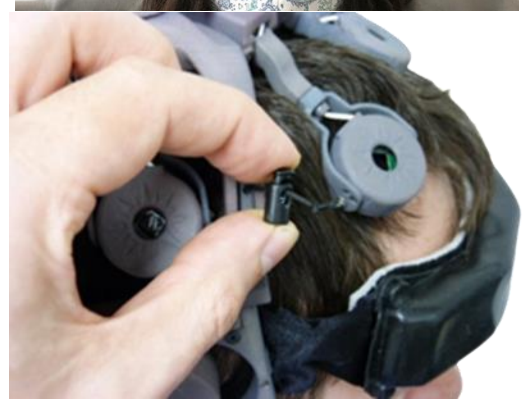
STEP 5 **PLACE HEADSET ON HEAD**	Hold headset with both hands, opening the back piece. Position the headset above and slightly behind the head, pulling the headset onto the head from back to front. Help open rear sensor arms on hub if needed.	
	Pull the headset directly down until it sits flush against the scalp with the forehead strap sitting against the forehead above the eyebrows. ○ The subject's ears should not be underneath the side plastics. Ears can be bent away from the headset. ○ If the forehead strap is falling into the subject's eyes, move it up and tighten headband slightly by turning knob in back of headset, only until the band is no longer falling into the subject's eyes. **The headset should still be relatively loose on the head to allow for hair adjustment, sensor adjustment, etc.**	
	Center the arrow on the front strap to the nose. ○ To adjust, hold headband from side plastics, opening it up to reduce friction while turning the headset in the appropriate direction.	
	The front band should rest approximately 1 cm above the eyebrows, with the skin smooth underneath. ○ To adjust, pull front band away from face and reposition. Do not push/pull the band up/down against the skin, as this can pull the skin and induce EMG artifacts.	

	Remove hair from under the forehead strap by using the utility tool, Q-tips, or fingers to bundle hair to the sides of the sorehead strap. o You can bend the forehead strap out to visualize the electrode tips to ensure that they are free of hair.	
	Slightly tighten headband to ensure that the hair does not fall back in between the forehead and electrode tips. In case of long hair, you need to part the hair now for all the sensors in the back of the headset, to ensure there is not excessive hair underneath sensors T5, T6, O1, and O2. o Insert a finger in between the head and the electrode o Push the electrode into its pod o Part the hair with fingers or tool or Q-tip o Releasing the electrode onto the parted scalp	
	Ensure that the headband is parallel to the transverse plane of the head. o Ask the subject to sit very straight and look forward to ensure that the headband is parallel to the floor.	

	Ensure that T3/T4 sensors are just above the ears. This may require pivoting the headset in order to align it properly. o Ensure that the forehead strap is still in place ~1 cm above the eyebrows.	
	Tighten headset by pushing the rear adjustment knob directly in and turning clockwise until the headset fits snugly but comfortably. o The wheel may feel tight to turn, but follow the subject's guidance and comfort level.	
	In case of hair growth under F7/F8, hold at the sensor locations and wiggle up and down a few times to ensure good contact between forehead skin and F7/F8.	

STEP 6 **ALIGN T3/T4**	Move T3/T4 sensors either forward or backward so that the hole in the back of those sensors align with the earholes on their respective sides. o The location on both sides should be either symmetrical or no more than one notch difference. • In case of asymmetrical T3/T4 locations, inspect the arrow on the front of the forehead strap and ensure that it is still centered. If not, repeat step 5	

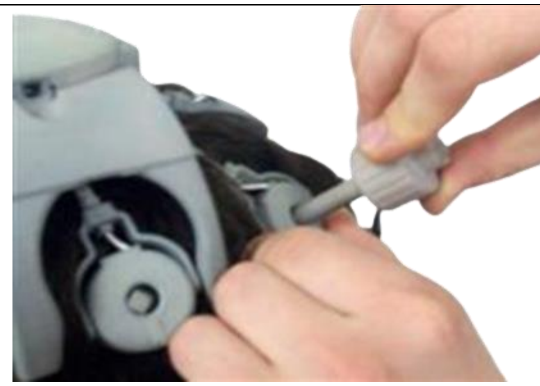
STEP 7 **ALIGN & TIGHTEN THE TOB HUB**	Rotate the top hub either to the left or right to align Fz with the arrow on the front of the forehead strap	
	Shift the top hub to the right or left so that the space between [C3 and T3] is equal to the space between [C4 and T4]. ○ You can check the distances using your fingers.	 
	Shift the top hub forward or backward to that the space between [Fz and the forehead strap] is equal to the space between [Pz and the backstrap]. ○ You can check the distances using your fingers.	 

	Press the top hub directly down by placing your flat palm on the face of the top hub and pressing down into the head until it makes contact with the scalp. o If, when you remove your hand, the top hub bounces back up, increase tension on the side elastics by pulling the elastics directly out at the same time and sliding the cord release toward the headset. • The tension on the left and right sides should be symmetrical so that the downward force on the top hub is optimized and equal on all sides. • Cord tension is set to balance between comfort and resistance to motion artifacts. You can ask the subject to walk, and you should see no movement of the headset or motion artifacts on the EEG signals. - If there is movement or motion artifacts, tighten the cords and rear adjustment knob slightly.	  

STEP 8 **SENSOR ADJUSTMENTS**	Use the provided utility tool to work the sensors through the hair ○ In case of long hair, it is important to part the hair underneath the sensors to ensure good contact is made between the electrode tips and the scalp. • First lift each of the sensors on the top hub, and part hair underneath them, placing the sensor back down in the parted hair.	 
	Press the sensor pod down, flush against the scalp, using two fingers (one on each side of the hole on the back of the sensor). Keep those two fingers on the back of the pod throughout the entire sensor adjustment process.	
	Insert the skinny end of the utility tool into the hole on the back of the sensor.	

<table>
<tr>
<td></td>
<td>
DO NOT PUSH DOWN on the sensor with the tool <u>while rotating</u>, this can cause discomfort to the subject. Rotate the sensors back and forth very lightly as described below to move hair from underneath the electrode tips:

Turn sensor right all the way. Stop when you feel resistance.
Turn sensor left all the way. Stop when you feel resistance.
Turn sensor right all the way. Stop when you feel resistance.
Turn sensor left all the way. Stop when you feel resistance.
Return sensor to center position (halfway between the full left and full right positions).
Quickly rotate the sensor partially left and right, back and forth, ~5 times to “jiggle” the electrode tips through any fine hair remaining under the pins.
When you are finished rotating that sensor, use the tool <u>to gently push the sensor straight down onto the scalp and hold for ~2 seconds</u>.
Doing so will press the inner ring onto the scalp, releasing some moisture from the scalp to help the Ag/AgCl electrodes start to equilibrate their microenvironment
While continuing to press down on the sensor pod with your two fingers, remove the utility tool.
It is important to hold the sensor pod against the scalp when removing the utility tool to ensure that good contact is maintained; otherwise, the sensor may pull away from the scalp when the tool is removed.

</td>
<td></td>
</tr>
</table>

	Complete the sensor adjustment process for the rest of the sensors.	

<table>
<tr>
<td rowspan="2">STEP 9

ATTACH EARCLIPS</td>
<td>Remove the earclip sensors from their magnetic holder on the backstrap.</td>
<td></td>
</tr>
<tr>
<td>Attach the earclips to the earlobes with the sensor face making contact with the back of the earlobe.
○ You can pull the earlobe taut to enlarge the surface area and ensure good contact between the skin and sensor.
○ The earclip sensor location can be adjusted on the ear for subject’s comfort. We recommend the sensor face making contact with the back of the earlobe, as there is generally little to no earwax or hair growth on the back of the earlobe.</td>
<td></td>
</tr>
</table>

STEP 10 **CHECK WITH THE SUBJECT ON THEIR COMFORT LEVEL**	Ask the subject how the headset is feeling. ○ If they report discomfort, you should release the pressure on the circumference by pulling the rear adjustment knob directly out, pushing it directly back in and retightening to a lesser degree. ○ If they report pressure around the forehead, you should insert the foam forehead spacers. Refer to **section 8.1.1** on forehead spacers for more information	 

STEP 11 **CONNECT ADDITIONAL SENSORS (IF APPLICABLE)**	If using ECG/EMG/EOG sensors, place on body and plug into Xx ports in back of the headset.	

STEP 12 **CONNECT THE HEADSET**	You are now ready to establish connection between your DSI-24 and your PC. o If using WIRED mode, plug mini-USB cable into headset, determine COM port, then launch software OR o If using WIRELESS MODE, pair Bluetooth, determine COM port, then launch software.	

STEP 13 **CHECK SIGNAL QUALITY**	Check impedance - <1MΩ Check RMS - <50 µV when subject is sitting still, not blinking Check Baseline Level - <|5000|µV Check for artifacts - EMG - CBA - Sweat	See Next Section

5 Inspecting Signal Quality

Data acquisition is performed using Wearable Sensing's DSI-Streamer software, which allows signal quality monitoring by:

1. Quantitative metrics related to electrode-skin contact.
2. Evaluation of the morphological features of EEG signals.

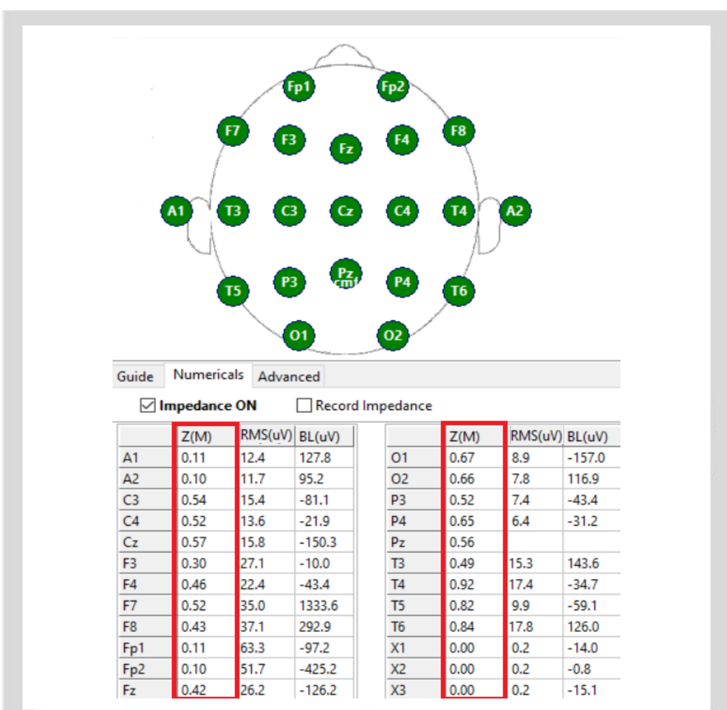
To monitor quantitative signal quality metrics: Impedances, Baseline Levels, and Noise, launch DSI-Streamer and check the Diagnostic box in the top right-hand corner (shown above right).

5.1 Impedance: (Z)

The contact impedance between an electrode and the skin is measured to assess the quality of contact. The EEG sensor and CMF reference sensor contact impedances can be monitored continuously during experiments, as the two impedance carrier frequencies are set at 110Hz and 130Hz and are thus out-of-band signals that do not interfere with EEG signal acquisition.

View impedances by checking the Impedance OFF box (label will change to Impedance ON when being monitored) in the Diagnostic pane. Sensor impedances will gradually go down in the first 1-5 minutes after the headset is donned.

The common mode rejection ratio (CMRR) is often impacted by the quality of the electrical contact to the scalp, therefore, for optimal operation, **sensor impedances should be <1MΩ**



	Z(M)	RMS(uV)	BL(uV)		Z(M)	RMS(uV)	BL(uV)
A1	0.11	12.4	127.8	O1	0.67	8.9	-157.0
A2	0.10	11.7	95.2	O2	0.66	7.8	116.9
C3	0.54	15.4	-81.1	P3	0.52	7.4	-43.4
C4	0.52	13.6	-21.9	P4	0.65	6.4	-31.2
Cz	0.57	15.8	-150.3	Pz	0.56		
F3	0.30	27.1	-10.0	T3	0.49	15.3	143.6
F4	0.46	22.4	-43.4	T4	0.92	17.4	-34.7
F7	0.52	35.0	1333.6	T5	0.82	9.9	-59.1
F8	0.43	37.1	292.9	T6	0.84	17.8	126.0
Fp1	0.11	63.3	-97.2	X1	0.00	0.2	-14.0
Fp2	0.10	51.7	-425.2	X2	0.00	0.2	-0.8
Fz	0.42	26.2	-126.2	X3	0.00	0.2	-15.1

If after pressing **Reset**,

Z<1 M, the sensors are making good contact with the scalp. Continue with data acquisition.

2 M> Z >1 M, use the utility tool to press the sensor in question down for ~1 second to release moisture from the scalp and facilitate the chloride exchange between the electrode tips and the scalp.

Z>2 M, use the utility tool to manipulate the hair under the sensor.

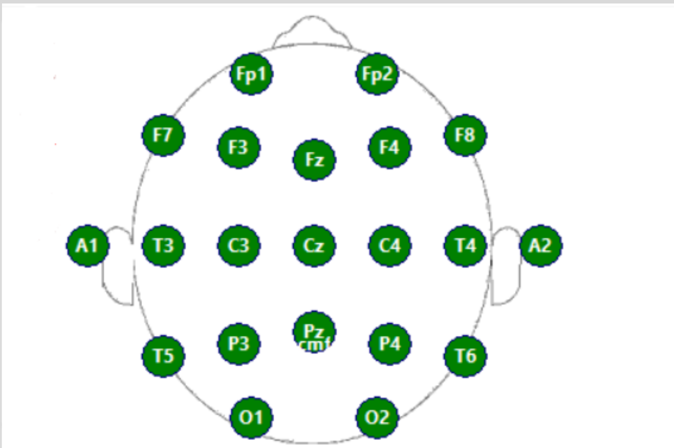
There is a “microenvironment” of saline that builds up between the electrode and the skin that takes some time to develop. This can be accelerated by pressing down on the sensor with the tool, which forces sweat out of the skin pores. This helps bring down the impedance

5.2 Baseline Level (BL)

Baseline Level (BL) is the approximate measure of the DC-offset of the sensors, reported in Microvolts (µV). This measure reflects the equilibrium of the chloride exchange between the Silver/Silver Chloride (Ag/AgCl) electrode tips and the skin's natural sweat that contains sodium chloride (NaCl).

BL will be very high after sensors are manipulated, as this disrupts the microenvironment of saline that builds up under the electrodes as the skin naturally breathes. BL will thus also slowly settle down on its own as the skin breathes.

For optimal operation of the sensors, **baseline levels should be <|5000| µV.**



Guide | Numericals | Advanced

☑ Impedance ON ☐ Record Impedance

	Z(M)	RMS(uV)	BL(uV)
A1	0.11	12.4	127.8
A2	0.10	11.7	95.2
C3	0.54	15.4	-81.1
C4	0.52	13.6	-21.9
Cz	0.57	15.8	-150.3
F3	0.30	27.1	-10.0
F4	0.46	22.4	-43.4
F7	0.52	35.0	1333.6
F8	0.43	37.1	292.9
Fp1	0.11	63.3	-97.2
Fp2	0.10	51.7	-425.2
Fz	0.42	26.2	-126.2

	Z(M)	RMS(uV)	BL(uV)
O1	0.67	8.9	-157.0
O2	0.66	7.8	116.9
P3	0.52	7.4	-43.4
P4	0.65	6.4	-31.2
Pz	0.56		
T3	0.49	15.3	143.6
T4	0.92	17.4	-34.7
T5	0.82	9.9	-59.1
T6	0.84	17.8	126.0
X1	0.00	0.2	-14.0
X2	0.00	0.2	-0.8
X3	0.00	0.2	-15.1

For proper operation of the sensors:
Baseline Level values should be <|5000| µV

BL can be reset by using the "Reset" button, which temporarily resets it to 0µV. The baseline will then rise to its current value and gradually settle back.

Normal operating range is below typically |1000| µV

NOTE: IT IS VERY IMPORTANT TO WAIT BETWEEN ADJUSTMENTS, AS EVERY TIME SENSORS ARE ADJUSTED, THE EQUILIBRIUM IN THE MICROENVIRONMENT BETWEEN THE ELECTRODE AND SKIN IS DISRUPTED AND WILL TAKE TIME TO SETTLE BACK DOWN. IT IS THEREFORE IMPORTANT TO WAIT ABOUT 1 MINUTE BETWEEN MANIPULATIONS OF A SAME SENSOR. ACCORDINGLY, WORK ALL SENSORS THAT NEED WORK BEFORE PRESSING RESET AND INSPECTING THEM.

5.3 Noise (RMS)

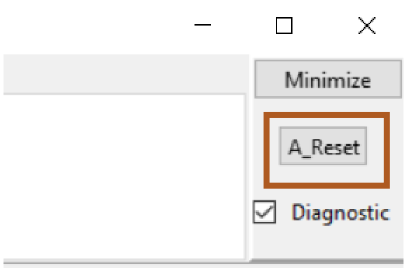
Noise (RMS) is the measure of RMS noise of the 1-100Hz signal on a sensor measured in µV.

In order to inspect for any unusual behavior, subjects should be asked to fixate a point, to reduce EOG, and relax their facial and neck muscles to reduce EMG, and not blink for a few seconds: At that point, **noise values should then be <50 µV**

	Z(M)	RMS(uV)	BL(uV)		Z(M)	RMS(uV)	BL(uV)
A1	0.12	6.9	177.1	Fz	0.22	4.9	69.9
A2	0.11	7.2	117.9	GSR2	NA	0.2	-4.0
C3	0.30	4.8	-3.0	O1	0.47	3.9	-1.5
C4	0.25	6.7	145.8	O2	0.44	4.3	-11.5
Cz	0.29	3.4	86.2	P3	0.38	3.7	57.7
EMG2	0.00	0.2	-11.0	P4	0.33	3.5	56.8
F3	0.20	6.8	52.0	Pz	0.39		
F4	0.18	5.6	145.2	T3	0.30	5.7	-14.9
F7	0.20	10.4	204.4	T4	0.24	5.6	39.7
F8	0.14	7.0	205.2	T5	0.56	4.4	-141.9
Fp1	0.11	6.5	198.3	T6	0.24	7.2	70.6
Fp2	0.11	6.3	150.7	X3:	0.00	0.2	-8.6

5.4 Reset Function

After donning, and anytime a sensor is manipulated, the **A_Reset** button should be pressed. This briefly shorts the inputs of the amplifier thereby removing any built-up charge that may have saturated the amplifiers and resets them into proper operation.



Once the impedances have settled to below 1 MΩ, the quality of the signals should be inspected. The following subsections illustrate good quality EEG recordings of wakeful brain activity, alpha activity, eye-blinks, and jaw clenches.

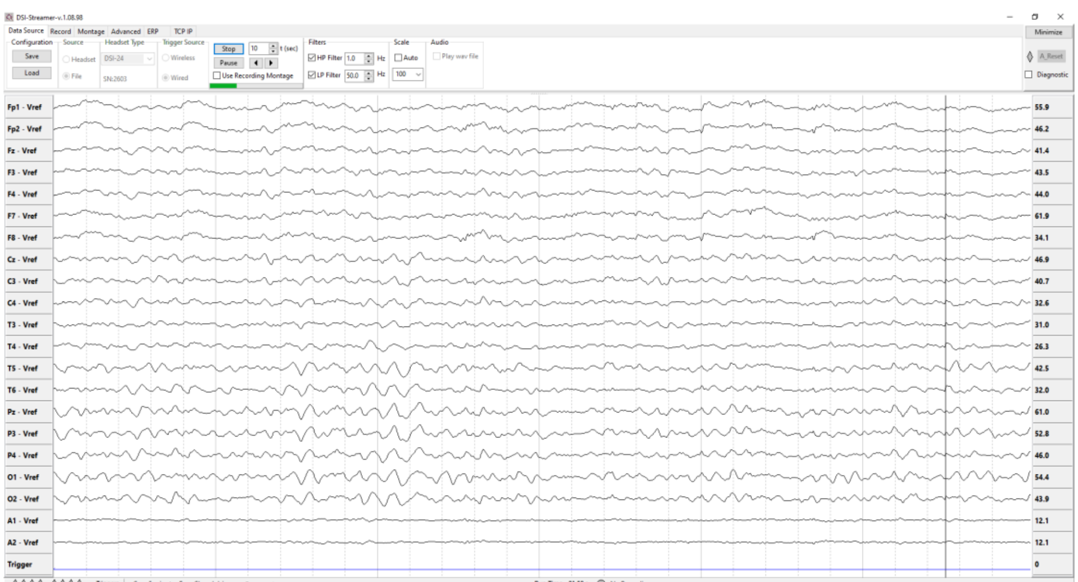
5.5 Eyes Open

EEG signals vary in shape and amplitude, frequency, and morphology, with age, wakeful state, cognitive load, and disease. During wakefulness, the signal generally is devoid of abnormal features, and looks like the traces shown in the representative screenshot.

5.6 Eyes Closed (Alpha Activity)

When most humans close their eyes, their brains produce alpha activity, defined as a rhythmic oscillatory activity with a frequency range between 8 and 12 Hz, and reaching > 50 µV in amplitude.

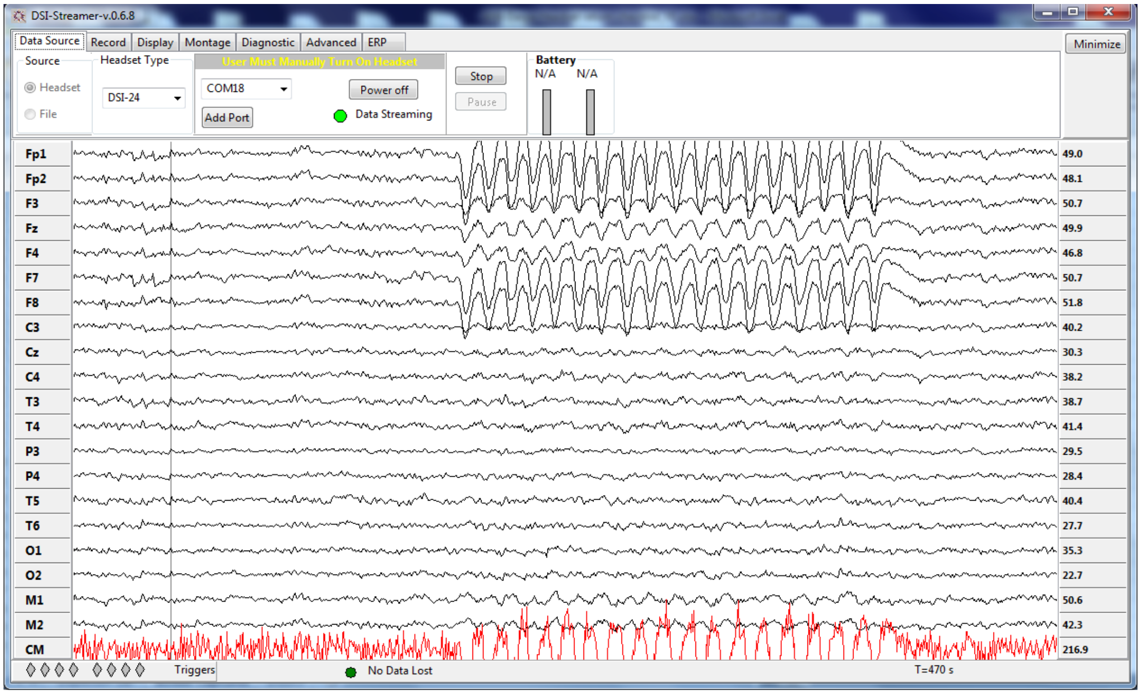
To measure alpha activity, ask subjects to close their eyes, and inspect the signals for oscillations such as the ones shown in the representative screenshot in, which shows two alpha spindles in the center of the screen.



Note that since not all people produce alpha activity with their eyes closed; eye-blinks or looking left and right or up and down are often used as a surrogate control protocol due to the large EOG signals they generate on the frontal electrodes.

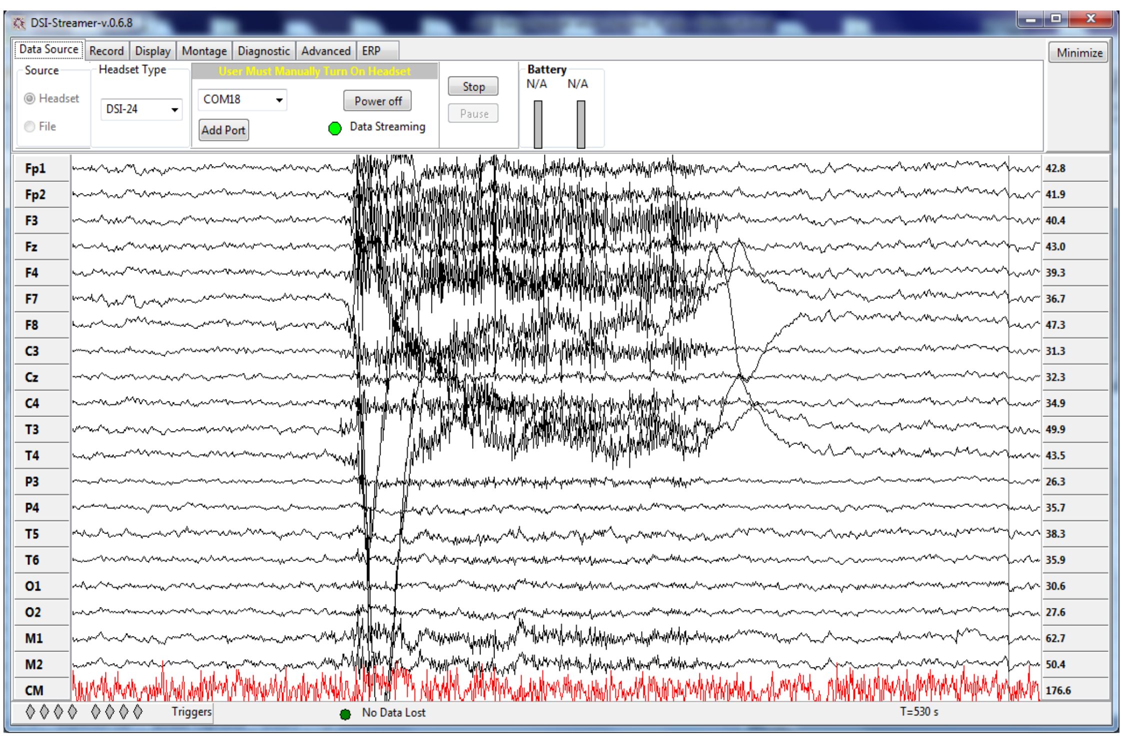
5.7 Eye Blinks

The representative screenshot shows rapid eye-blinks in the frontal sensors. Subjects should be instructed to blink rapidly to produce such signals.



5.8 Jaw Clench

Jaw clenches generate a large electromyographic (EMG) potential on all electrodes.



5.9 Testing Resistance to Electromagnetic interference

To test that the Faraday cage is making good contact and effectively shielding the DSI-24 sensors, the experimenter should run a simple foot tapping test, where large triboelectric charges are injected on the headset wearer's body by asking the wearer to tap their own foot on the ground, or having the experimenter tap their foot and place their hands near the headset. You have passed the test if you see no change in any of the traces on the EEG while tapping.

The figure below is an example of a failure of the tapping test. The red line is a visualization of the EMI artifact on the body. This feature of visualization is only available on the DSI-24. As you can see, when a tap occurs, the large red spike represents this tap. Simultaneous to the tap, a spike in channels F7 and F8 occurs. This is suggesting that the triboelectric artifact is not being protected against by the shielding on the system. In order to fix this, the experimenter should press down on the faraday cage on the affected sensors.

(Note: In this case, F7 and F8 do not have Faraday cages as their pins do not go through much hair and thus typically have sufficiently good contact to not require Faraday cages. However, in this case, the wearer had long hair under the electrode tips, which would have required to be brushed out of the way or some sensor manipulation)

5.10 Sweat Artifact: Pop and Slow Waves

Sweat negatively affects EEG signal quality, both in wet and dry electrode systems, however, dry electrode systems are more susceptible due to the lack of gel to buffer the sweat. Sweat artifacts are characterized by pop spikes (Figure 13) or large and low-frequency (around 0.25- to 5-Hz) oscillations (Figure 13) and occur whenever there is a rapid change in the ion equilibrium between the electrode and scalp. This can also manifest as large amplitude artifacts and wandering channels which heavily distort the signal and create a high level of noise. Electrode-sweat equilibrium is not stable. Like a GSR response on your head.

Sweat is caused by 5 sources principally

1. Internal heat (person was just working out or moving)
2. External heat (it is hot and/or humid outside)
3. Stress
4. Illness (certain diseases, even a cold or fever can lead to sweat)
5. Certain foods (spicy food)

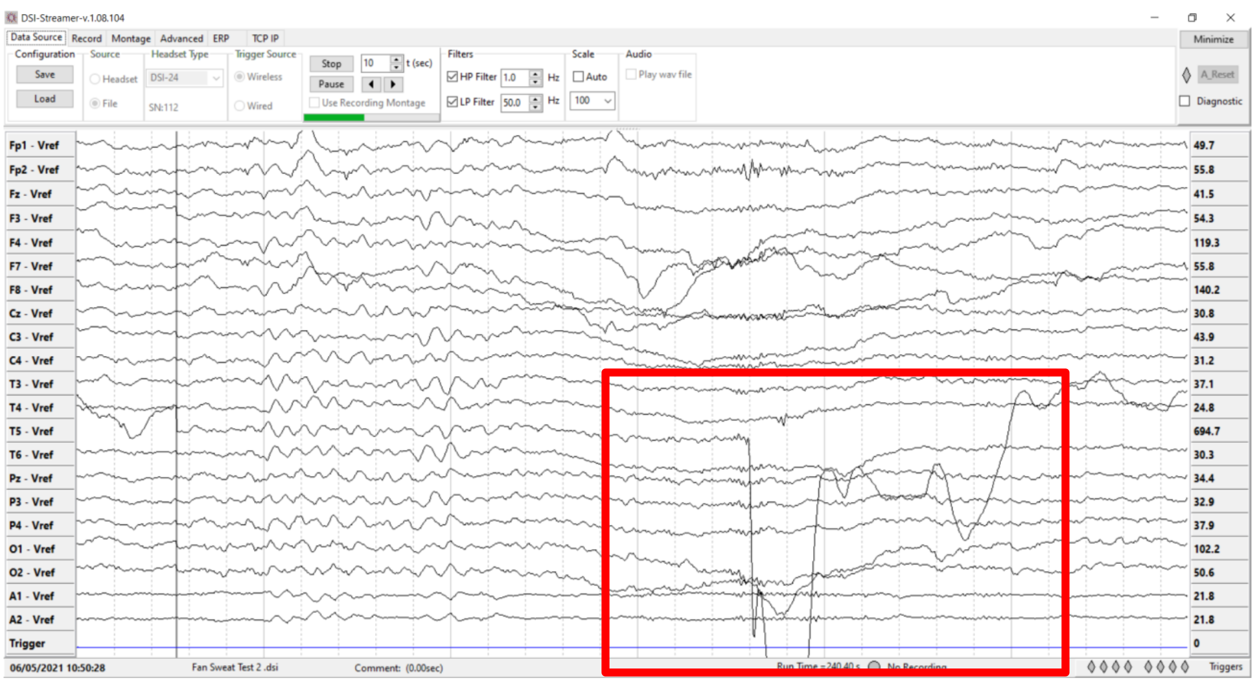


Figure 13. Example of sweat artifacts beginning to show. Note the pop-spikes in the red box

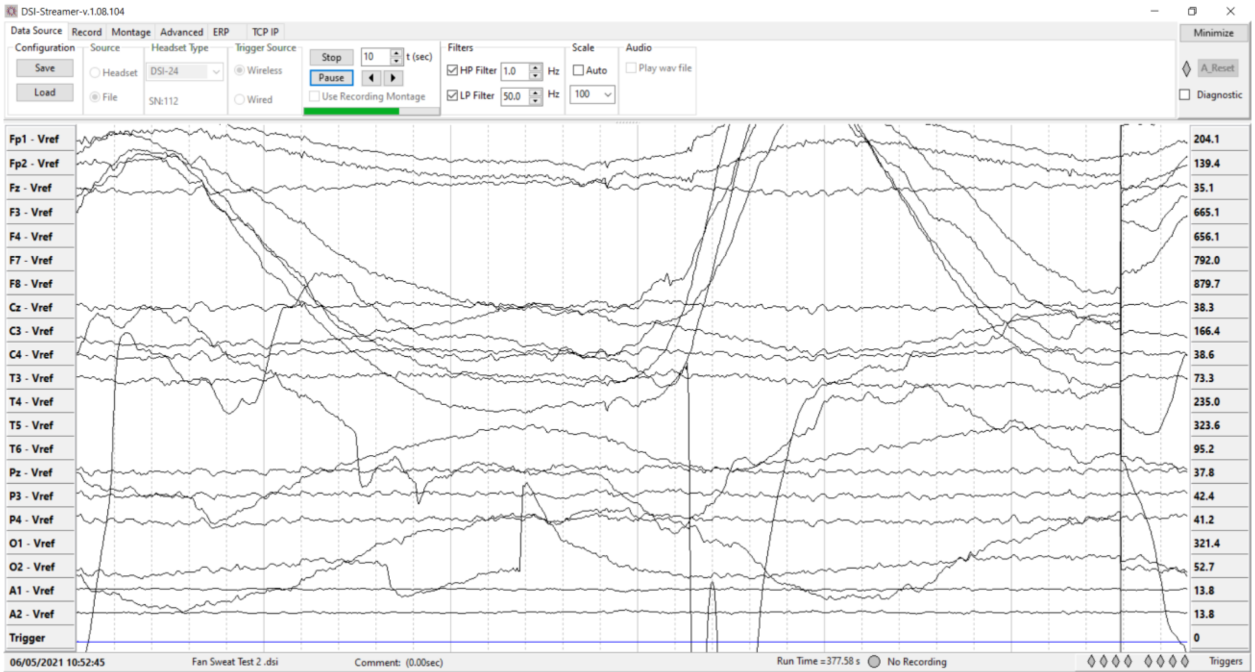


Figure 14. Example of extreme sweat artifact on EEG data

To mitigate sweat artifacts:

- Ensure users are rested and the environment is cool and dry (turn up AC).
- Give people 10+ mins to recover from exercise if they were just sweating due to exertion.
- If people are moving, ensure that movement is not too vigorous so as to induce sweat
- Reduce stress by talking to subjects and ensuring they are comfortable. Be aware that people are not always comfortable when they are being scrutinized (or their EEG), and that the process of donning can be uncomfortable to some people who prefer larger personal space
- In extreme cases, you can bring a 12+ inch fan and put it behind the person so as not to blow air in their eyes.
- In even more extreme cases, you may need to use additional artifact removal software.
- Please note that sweat makes electrodes slippery and thus makes them more sensitive to motion artifacts

We recommend you watch this video to learn about sweat artifacts and how to deal with them.

DSI Signal Quality: https://youtu.be/6juYPfUCEbA (*You can skip to time point 11:19*)

5.11 Cardioballistographic Artifact

Cardioballistographic Artifacts (CBA) are rhythmic oscillations that are due to the micromotion induced by blood throbbing in the arteries and may appear on one or more sensors. These artifacts are more likely to appear on sensors that are directly over a blood vessel. Figure 14 shows an example of CBA, where CBA is most prominent on C3, and also present on P3 and F8 albeit less prominently

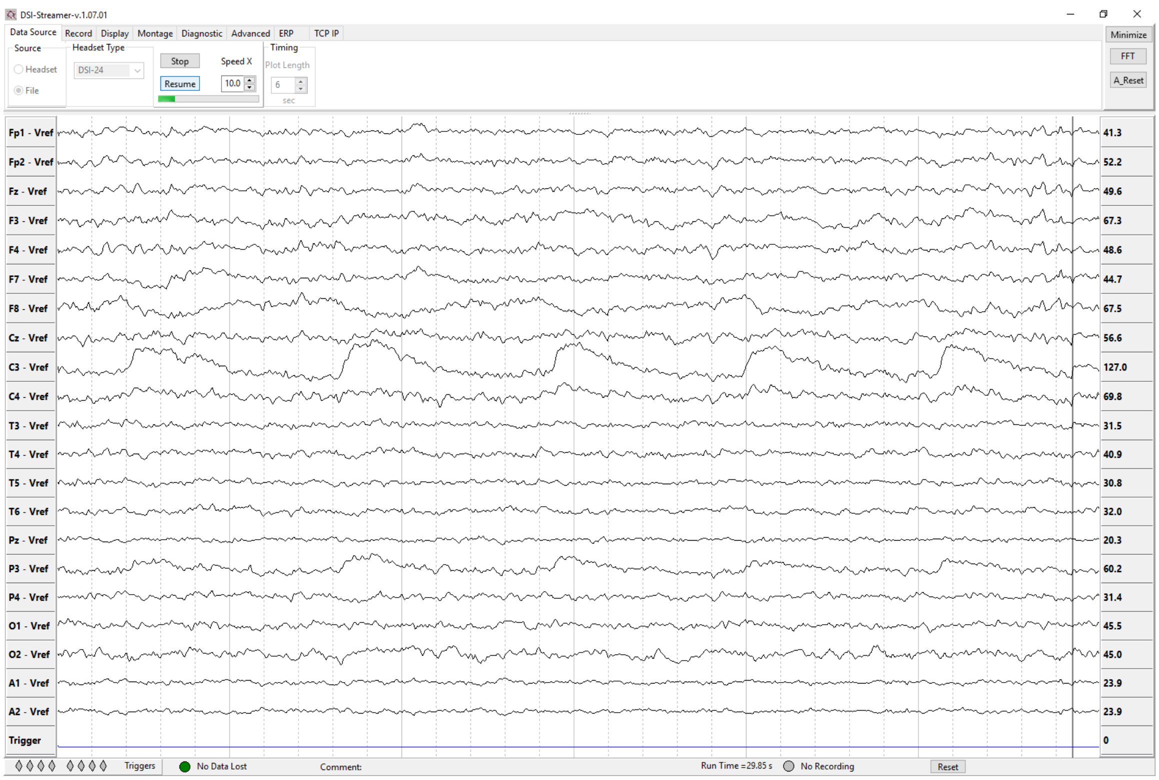


Figure 15. Example of Cardioballistographic Artifact (CBA), which can be seen on C3, P3, and F8.

On occasion, the artifact can disappear without intervention by the experimenter, but this cannot be relied upon. However, CBA can usually be easily removed by moving the electrode tip slightly.

Sensors should be moved 1 or 2 mm to one side inside their pod using the sensor manipulation tool. The amplifier should be Reset either by pressing on the Reset button in the DSI-Streamer software or by pressing on the Power button on the headset one time. This will restore signal to the sensor. Observe the signal for 10-30 seconds, if the CBA did not go away, then move the sensor to the opposite direction by 1-2 mm, Reset and observe. Most of the time the CBA should be eliminated by one or two movements. If not, then rotate the sensor using the manipulation tool, then Reset and Observe.

In extreme cases, where CBA does not go away with the above procedures, you may lift the sensor and rub it scalp with a Q-Tip soaked in Isopropanol for 3 seconds under the area where the electrode would make contact, and replace the sensor, work it through hair, Reset and observe.

Please note that CBA can recur, and signal quality should be monitored throughout the course the course of the recording, to mitigate artifacts.

5.12 Motion Artifacts

The sensors' support is designed to minimize relative motion between the sensor and the subject, and also to maintain a constant pressure on the scalp. However, if sensors are not making proper contact on the scalp, motion artifacts can be induced.

Motion artifacts are large interfering signals detected by an EEG sensor that are induced by the patient's motion, either due to electrode displacement against the scalp or deformation of the skin.

Our DSI systems are resistant to motion artifacts due to multiple design factors, both mechanical and electronic, at the sensor and headset levels. These designs allow our systems to acquire high-quality EEG signals with greater than 120dB CMRR against Electromagnetic Interference (EMI) and triboelectric charges, and to be highly resistant to motion artifacts. Thus, subjects can walk and move casually in the environment without the introduction of electrical or mechanical artifacts. The sensors are double spring-loaded to ensure stability against small movement within a certain range, and the headsets can be tightened to provide additional stability against headset movement.

In order to evaluate the headset's good fit and its degree of motion artifacts, ask the subject to perform activities normally expected in light ambulatory environments (e.g. walking, sitting down). The level of artifacts can be estimated by the increase of the noise compared to the baseline measured when the patient is still.

If motion artifacts are detected with casual user motion, that is an indication of poor sensor positioning, and the sensos should be pressed down with the tool, and or the headset tightened, and the testing above repeated to obtain adequate resistance to motion artifacts.

Mitigations and Limitations: following are suggestions for getting the best performance during motion:

Headset adjustments: To reduce the likelihood of motion artifacts, you can tighten the headset at 2 places: the boa wheel in the back of the headset, and the elastic cords. The boa wheel should be tightened first, as much as possible yet comfortable. Next, you can tighten the elastic cords on the sides, normally, for seated use, you can test if it is tight enough by pressing down on the top hub and seeing if it bounces back up; you want to tighten it enough so it does not bounce back up when you remove your hand; for ambulation, you may need to tighten this more after you ask the subject to walk and you look for how any stepping related artifacts on any sensors. If you are seeing artifacts on just 1 sensor or 2, then you should adjust those sensors individually, by pressing them down with the tool first AND fingers second. If the motion does not go away, lift the sensors, and move the hair from under them away as much as possible, reposition, work through the remaining hair, and press down. You should be able to get the subject to walk casually without seeing any artifacts in the EEG data. When testing artifacts, ask the subject to fixate on a single point and try not to blink when walking backwards and forward, to avoid eye movements. You can also instruct the subject to avoid strong stomping with their feet when walking. Please note that there is a small trade-off being long-term wearability comfort and resistance to motion, in that you may have to tighten the headset more than usual, which may make it slightly less comfortable for extended wear.

Shielding: Of course, you already know to try and get impedances below 1MOhm for recording good EEG signal. And you may recall that the sensors each have their own Faraday cage that acts as a shield against EMI. Checking impedance lets you know the inner electrodes' contact, but it does not tell you how well the Faraday cage is making contact with the scalp. To test that, you should put your hand near the subject's head, without touching the headset, and stomp your foot vigorously, as if you were kicking an invisible soccer ball, but hitting the floor instead. This will create large static discharges, which would be picked up by any poorly protected sensors. If you see nothing, that's very good, and you can proceed with testing for motion. If you see some artifacts being picked up on one or 2 channels, you need to press those down with your fingers (pressing with the tool presses the inner electrodes, pressing with fingers presses Faraday cage for the top hub sensors, the ones in the band or Pz, can only be pressed with the tool). If you want to visualize the EMI artifact, you can add the CM channel in the montage tab of DSI-Streamer. Then you will see the artifact injected on the subject every time you stomp your foot. You should be able to see the artifact on the CM channel but not in any EEG channel. This test ensures that the shielding is good on all the sensors to eliminate any EMI interference that can happen as they move.

Movement: There are, however, some limitations to be aware of as the headsets have mass, and thus momentum, and so rapid accelerations or decelerations can lead to headset movement, which if too large can lead to motion artifacts in the signal. So, you should avoid rapid movement, such as jumping or large foot stomping, or shaking the head fast. Usually, sensors settle back down after such vigorous movement, but you should be careful as changes in sensor position due to rapid movement may disrupt the contact between the electrodes and the scalp, leading to poor contact impedances and poor signal quality. Furthermore, the headset is designed to be on the head in an upright position, so be careful if asking the subject to bend down. This can be mitigated a bit by increased tightening of the headset as described above. You should be able to walk, move arms, head, legs, freely, as you might do in a normal day at the office, without introducing any visible artifacts.

EMG/EOG: Of course, head movement and changes in postural position can also lead to the introduction of EMG artifact. Even when a subject is sitting, it is important they keep their brows, neck and jaws relaxed and limit side to side eye movement. If the subject were moving from standing to crouching and constantly moving both their head and eyes side to side in search of a hidden object, you should be aware that these can introduce EOG/ EMG artifact into the signal.

Sweat: Even more importantly, if the movement are vigorous, and lead to sweating, you will see sweat artifacts, which will initially manifest as large pop-spikes on a few traces, and then if the sweating increases, will become very large artifacts on all channels that can mask all the EEG signal. In addition, sweating decreases the friction between the electrode tip and scalp, and thus increases susceptibility to motion artifacts. It is thus critical that you avoid sweating, which can be achieved by keeping the room cool, and potentially adding some fans (blow air into the back of the subjects not their face to avoid blinking).

In summary, you should be able to get very clean EEG with proper adjustments and with a certain range of motion. If you are not able to get this, please let us know so we can help you troubleshoot.

We recommend you watch this video to learn about motion artifacts and how to deal with them.

DSI Signal Quality: https://youtu.be/6juYPfUCEbA

6 Maintenance, Cleaning, and Storage

6.1 Removing the Headset

STEP 1 **TURN OFF THE DSI-24**	Press and hold the **POWER** button on the front panel for ~8 seconds to turn off the headset. o The **STATUS** LED will flash Green and the **ERROR** LED will flash Red indicating that the system is turning OFF. o Once you release the button, it will be OFF o You can check that it is OFF by pressing the STATUS button, which should NOT lead to any LED's lighting up.	
STEP 2 **LOOSEN HEADSET**	To remove the headset, loosen all adjustments. o Loosen top hub by releasing the tension on the cords. o Loosen headband by pulling the rear adjustment knob directly out. o Pull the forehead strap out from the forehead. o Be careful that the forehead strap does not fall into the subject's eyes.	
STEP 3 **REMOVE HEADSET FROM HEAD**	Remove headset front to back, by slowly lifting the front of the headset off of the subject's head. o Using one hand to hold the headset, use the other hand to smooth the subjects hair down so it is not being pulled by the electrode tips.	

		
STEP 4 **CLEAN HEADSET**	Clean headset as advised in the following section.	

6.2 Cleaning the Headset

In order to maintain signal quality, and furthermore in the interests of hygiene, it is recommended to clean the sensor components that come in contact with the subject's skin after every recording session. The sensor components parts that come into subject contact are:

- Sensor electrodes (inner & outer electrodes)
- Replaceable foam pads

Recommended cleaning supplies for the DSI-24 system are:

- Battery-operated soft bristle brush (provided with DSI-24 system)
- Cleaning solution – Wearable *Sensing* recommends 70% Isopropyl Alcohol

Step 1: Pour a small amount of cleaning fluid into a container. Wearable Sensing recommends using the small container provided in the case.	

Step 2: Turn on the cleaning brush by pressing the POWER button.	
Step 3: Dip bristles of cleaning brush into cleaning fluid.	
Step 4: Using the soft bristle brush, gently clean the electrodes by applying the cleaning solution to all of the pins by holding the power brush against the electrode tips for at least 1 second each.	
Step 5: Brush the surface of all foam pads and forehead strap with the cleaning solution and brush.	

Step 6: To clean the earclip sensors, dip a piece of clean tissue or paper towel into the isopropyl alcohol solution. Clamp the earclip around the tissue to disinfect the sensors.	 
Step 7: Allow the sensors to dry completely before donning on another subject. The drying process can be expedited using compressed air.	

6.3 Replacing Electrode Tips

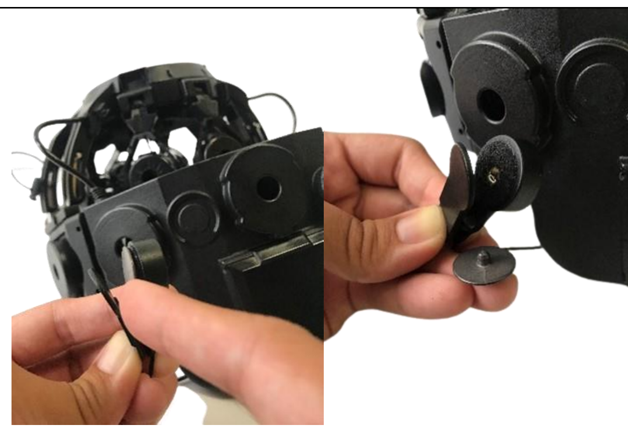
Wearable *Sensing* recommends that the sensor electrodes should be replaced after approximately 100 donning sessions to keep signal quality high. Try to keep track of the number of donning sessions so you know when it is time to replace them.

Alternatively, electrodes should be also replaced if there is build-up of dirt and oils from hair, if they are noticeably scratched, or if signal quality is consistently poor.

You should visually inspect the electrode tips to see when the Ag/AgCl coating has started to wear away. Ag/AgCl is GRAY. When the electrode tips begin to appear a shiny SILVER (right electrodes in the photos below), it is time to change the tips.

The procedure for replacing electrodes is presented below.

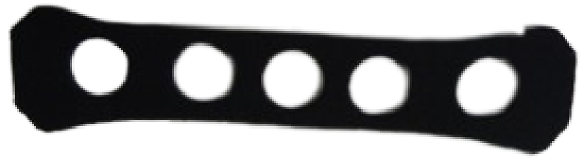
Step 1: Removing the Inner Electrodes	Unscrew the electrode tips by inserting the thick end of the provided utility tool into the pod and rotating **<u>counterclockwise</u>** until loose. ***DO NOT PUSH DOWN on electrode while rotating or you may damage sensor. The sensor locks and allows you to screw or unscrew electrode tips when the spring is full extended.***	

Step 2: Replacing and Attaching the Inner Electrodes	Screw new electrode tips by inserting them into the sensor pod and using the thick end of the provided utility tool and rotating them **clockwise** until secure. ***DO NOT OVER TIGHTEN. Over-tightening the electrode can damage the connection on the sensor, rendering the sensor unusable.***	
Step 3: Replacing the Electrodes on the Front Strap	The flat electrodes on the front strap must also be replaced. To do this, slowly take off the foam pad on the front strap, and unscrew counterclockwise the flat electrodes with your fingers	
Step 4: Replacing and Attaching the Earclip Sensors	Using a fingernail, gently pop the earclip electrode out of its housing. The sensor should easily pop in and out. Replace the old electrode with a new one buy placing it in the hole (shown here) and gently pressing until pops into place.	

6.4 Replacing Foam Pads

Wearable *Sensing* recommends that the foam pads be replaced if there is buildup of dirt and oils or if they are noticeably worn or torn.

The procedure for replacing the foam pads is presented below.

The foam pads shown here can be replaced by separating the Velcro and lifting the foam pad from the headset.	Foam pad for forehead strap	
	Rear foam pad	
	Crown piece foam pad **There are three "tabs" on the crown piece foam pad that are closer together in distance than the rest, indicating the top of the foam pad. Insert accordingly.**	

6.5 Battery Charging and Replacement

The DSI-24 system is supplied with two Li-ion batteries (NB-4L, 3.7 V). The system can operate with a battery installed in either of the left or right battery compartments, or with a battery in both. The run time with two fully charged batteries is about 20 hours (or 10 hours with a single battery).

The batteries should be changed immediately when the yellow battery LED (**Error! Reference source not found.**) starts blinking every 5 seconds (Very Low Battery indication). The batteries should also be changed in the event that, upon a single press of the STATUS button, only the **YELLOW** battery LED lights up (either a single flash, or periodic flashing).

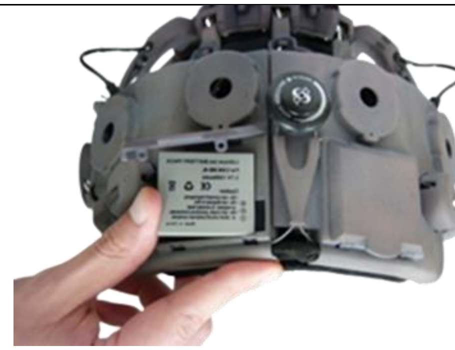
The batteries on the DSI-24 are hot swappable, so as long as at least 1 battery is in the headset, the other battery can be swapped during acquisition, and data will not be interrupted.

Batteries should be charged using the provided battery charger.	

Replacing one or both batteries when headset is turned off	Turn the headset OFF by pressing and holding the POWER button down until the red and green lights flash (approximately 8 seconds).	

	Open the battery compartment(s) located at the back of the headset.	
	Remove battery from its compartment, replacing it with a charged battery by inserting it in the proper orientation. Close battery compartment. *Note that the connection terminals for both batteries are towards the center – hence one battery is "upside down" relative to the other.*	 

Replacing batteries without stopping data acquisition	During data acquisition, open one battery compartment located at the back of the headset.	

	Remove battery from its compartment. Headset will continue to operate using power from the 2nd battery.	
	Replace battery with a charged battery, and close door of battery compartment. This step can be repeated for the 2nd battery, if desired.	

6.6 Packing, Storage, and Transport

To avoid damage, the DSI-24 should be stored in the case in which it was received.

To transport the DSI-24 place all items back in their designated foam slot. For the headset itself, place the orange “Wear-a-Ball” that came with the headset back in between the sensors. Ensure the sensors lay flat against the semi-circular pad and place the headset in the case with the coronal hub facing up and the buttons facing you.

STEP 1 Squeeze Wear-a-Ball with logo facing you.	
STEP 2 Insert Wear-a-Ball into headset.	
STEP 3 Release grip on Wear-a-Ball within headset.	
STEP 4 Tighten headset around Wear-a-Ball.	
STEP 5 Place headset Wear-a-Ball side DOWN into the provided carrying case.	

**Please note that if traveling by plane, the amount of alcohol does not exceed the fluid restriction limits, however it is not contained in a 1 quart/liter zip-top bag so we recommend that you not fly with a full container of 70% isopropyl alcohol. Store it in the case to prevent UV light from wearing away the electrode tips coating

1. Please tighten the headband with the wheel in the back then place it with the sensors pointing down into its space in the case.
2. Carefully replace all elements back into their space in the case, and check off the packing label so that there is a record of what was shipped back, we'll double check it when we receive it, and use this sheet to make sure you get everything that was shipped back.
3. Either tie the case with zip-ties, OR pack the case in a box to avoid the box opening during shipping

7 Triggers

For data synchronization and trigger marking, Wearable Sensing also offers a Wireless Trigger Hub that is intended to receive input signals from a number of upstream systems and distribute event markers to downstream devices.

Wearable Sensing's Trigger Hub system is an electronic hub that is intended to receive input signals from upstream systems and distribute event markers to downstream devices. It is designed to simplify the process of consolidating up to 8 trigger sources into a single multi-channel output as an input to Wearable Sensing's Dry System Interface (DSI) hardware. The use of standardized input connectors (BNC connectors, 3.5mm sockets, DB-25 D-subminiature connector) allows a wide range of devices to be connected to the Trigger Hub using standard cables.

An additional benefit of the Trigger Hub design is that it allows synchronization across multiple data sources that are distributed across multiple systems, each of which running at its own clock rate. One such case commonly experienced in EEG experiments involves synchronization of EEG and eye tracking measurements, where the inevitable clock drift that arises between two systems during extended measurements creates difficulty in aligning data to events across the two systems.

One approach to synchronization of devices is to distribute triggers from a single source amongst multiple devices. In this way, trigger events can be used for time synchronization across systems. A specific feature addressing the issue of synchronization is the Trigger Hub's AutoTrigger function, an internally generated 1 Hz trigger signal that can be distributed to all outputs, which can act as a signal used for timing alignment between multiple acquisition systems.

There are dedicated inputs on the Trigger Hub for 4 different types of inputs:

1. Signals between 0 and 20 V
2. Line-level audio
3. Switch inputs
4. Output from a PC's parallel port.

Input voltages that drive a trigger event can be selected via a thresholding circuit on each signal. The threshold level is common to all inputs and can be adjusted between 0.6 V and 6 V by the user. The resulting triggers are consolidated on an output parallel port that can be connected to Wearable Sensing EEG headset with a cable. In addition, triggers from the input parallel port are distributed across the connectors on the output panel. The trigger output voltage is 0-5 V, which is sufficient to drive the trigger inputs of common devices.

A trigger cable supplied with the Trigger Hub system is used to transfer trigger signals from the Hub to a headset. Also provided is a wireless receiver that can be plugged into a Wearable Sensing EEG headset and receive multi-channel trigger information encoded into a byte of digital information.

For more information about the Wireless Trigger Hub, please contact sales@wearablesensing.com

8 Subject Safety

8.1 Headaches

It is important to continuously check in with the subject on their comfort level. If the subject reports a headache, ensure that the front band is 1 cm above the eyebrows to avoid the headband sitting on the soft tissues of the brow bone. You may also loosen the headband and/or the top crown.

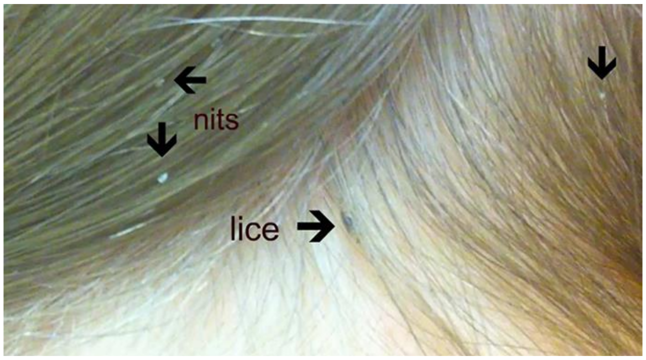
8.1.1 Forehead Spacers

Sometimes, the subject will report a general feeling of discomfort along their forehead and temples. This pain can be alleviated by inserting the two forehead spacers provided.

- If you have a continuous study with repeated subjects, it may be worth noting which specific subjects benefit from the use of the forehead spacers, so you are able to insert them prior to donning in consequent sessions.

8.2 Lice

Prior to donning, you should inspect the subject's scalp. If you see any evidence of lice, do not use the headset on this subject.



If you discover that the subject has lice after donning, it is necessary to thoroughly clean the headset using the protocol below.

1. Blow dry the headset on HIGH heat for 10 continuous minutes to kill lice, eggs, and larval.
2. Thoroughly clean the headset with the provided alcohol and brush to remove dead lice, eggs, and larvae.

8.3 Skin Issues (Pimples, Scars, Scabs, etc.)

Prior to donning, you should inspect the subject's scalp. If you see any evidence of open sores, pimples, scabs, etc., do not use the headset on this subject.

The DSI-headsets are designed to be non-abrasive, which decreases the chances of broken skin/blood contact. However, if your subject has open sores, pimples, scabs, etc., and the headset comes into contact with blood, you must follow the cleaning instructions below:

1. Using the provided power brush, clean the headset with a soapy water solution for 5 minutes.
2. Clean the headset again with the provided alcohol solution. The total wet contact time between the brush bristles and headset must be no less than 5 minutes.

8.4 Hair Products (Gel, Conditioner, Hairspray, etc.)

The subject should avoid using heavy gels, hair products, conditioners, etc. prior to donning the headset.

Many hair products (like the ones shown below) can impede the connection between the electrodes and the scalp.

You should ask the participants prior to arrival to ensure their hair is clean and dry. Wet hair can shunt the electrodes, consequently resulting in poor EEG data.

9 Troubleshooting

9.1 Troubleshooting Guide

If, after manipulating electrode tips through the hair and then waiting for

- The contact impedances to drop, and/or
- The signal quality to improve,

If it is observed that many of the sensors continue to produce poor quality data, and then the following steps should be taken:

1. Turn off the DSI-24 system.
2. Clean the electrodes (or replace them if they are worn out).
3. Ensure that the electrodes are not damaged and, if replaced, that they are screwed on well.
4. Contact impedance higher than 5MΩ may indicate poor contact between the sensor and electrode (e.g. the thread is dirty).
5. Don the system as directed.
6. Ensure proper positioning of the sensors in relation to the head.
7. Ensure that there is not a nearby source of large EM fields or microwave radiation.
8. Turn on DSI-24 system and monitor data using DSI-Streamer software.

Refer to the DSI-Streamer software User Manual for details about troubleshooting using the Diagnostic tab in the main window of the DSI-Streamer interface.

10 DSI-24 Quick Donning Guide

This Guide is meant to be a supplement to, not a substitute for, reading the user manual, watching tutorial videos, and attending training.

1. Visually Inspect Headset (check electrode tips, sensor arms, tightening wheel, T3/T4 slider)
2. Measure head circumference for fit (**54-62 cm** is optimal, 52-54 cm might be loose).
3. For individuals with long hair, let their hair down and part it above the ears
4. Prepare the headset for donning and turn it on (in wireless mode it will start to flash green).
5. Place DSI-24 headset on head (help open rear arms as you are pulling it down from the band).
   - 5.1 Bring band to ears. (Ears should be bent away from headset, not under it).
   - 5.2 Slightly tighten headband using tightening wheel, just so front band does not fall on eyes.
   - 5.3 Adjust hub sensors so they are flush with head using fingers.
   - 5.4 Center front arrow in headband to nose.
   - 5.5 In case of long hair, bundle hair away from sensors in headband using tool or Q-tip.
   - 5.6 Front band should rest approx. 1 cm above eyebrows; skin should be smooth underneath.
   - 5.7 Brush away hair from under front strap.
   - 5.8 Tighten headset till comfortably snug.
   - 5.9 In case of hair growth under F7/F8, hold at F7/F8 & wiggle up and down a few times.
6. Adjust T3 and T4 sensors to align over ear holes.
7. Adjust top hub to:
   - 7.1 align Fz to arrow on front band
   - 7.2 ensure that C3 and C4 are equidistant from headband.
   - 7.3 ensure Fz and Pz are equidistant from the headband.
   - 7.4 Tighten elastics with cord lock so the top hub does not bounce (tighter for ambulation).
8. Using tool, rotate sensors: 2x 90° slowly; 2x 45° quickly; press down 1 s; and remove tool.
   - 8.1 If the subject has long hair, lift each sensor, part hair and place sensor back down.
   - 8.2 Repeat Step 8 for all sensors (do not forget Cz).
9. Attach ear clip sensors (sensor behind the ear).
10. Ensure subject is comfortable, adjust as needed to provide additional comfort
11. Connect additional sensors if applicable
    - 11.1 If using ECG/EMG/EOG sensors, place on body and plug into Xx ports in back of headset.
    - 11.2 If using wired mode, plug u-USB cable into headset, loop to attach to **back** arm of hub.
    - 11.3 If using triggers, plug dongle or cable into trigger port, loop to attach to **front** arm of hub.
12. Connect the headset to PC
    - 12.1 Pair Bluetooth, determine COM port, then launch software.
13. Check impedance, check for artifacts (EMG, CBA, sweat), and adjust as necessary.

WARNING

The DSI-24 is not a medical diagnostic instrument. It is not intended for clinical use. This device is intended for research use.

Wearable Sensing makes no warranty concerning the safety of the DSI-24. It is designed according to ANSI safety standards, but is not certified to any specific standard.

The DSI-24 is intended to measure EEG signals from human subjects. Use may require IRB approval, and subjects should be informed that this device is not a medical instrument. Any other information other than EEG signals gathered from this device, either implied or otherwise, is not covered by the intended use of this instrument and is therefore not the responsibility of Wearable Sensing or its subsidiaries.

The DSI-24's wireless communication operates in the license-free worldwide 2.4GHz Industrial Scientific and Medical (ISM) band; however, the wireless system is not certified to any specific standard.