DSI-24

EEG HEADSET

USER MANUAL

Version 0.8

© 2013-2015 Wearable *Sensing*

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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 preliminarily tested for performance and safety. However, this is a research instrument, and Wearable Sensing makes no warrantee 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 "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.

2. System 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 core technology of the system consists of ultra- high impedance dry sensor interface (DSI) sensors that work through normal hair and require no prior skin preparation, nor the use of conductive gels to facilitate electrical contact with the scalp. The sensors can be individually adjusted to improve their contact with the scalp.

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 is available with options to measure from either the mastoid locations (M1, M2) or earlobes (A1, A2). A reference sensor (Common Mode Follower, CMF) is placed at the nominal Pz position.

A further 3 inputs have been included to facilitate measurements from additional Wearable *Sensing* sensors. These inputs can be configured to support single sensors (e.g. for EMG, EOG), differential measurements between two sensors (e.g. HEOG, VEOG, ECG), or the average between 2 sensors (e.g. linked-ear reference).

The headset and sensors have been designed with user comfort in mind so that the contact pressure, due to the downwards force holding the sensors against the scalp, remains within comfortable limits. In addition, the padded back-piece has been integrated into the headset to allow for the wearer to rest in the supine position

This User Manual has been divided into the following main sections:

1. System Components
2. Getting Ready for Data Collection with the DSI-24 Headset
3. EEG Data Acquisition Using DSI-24 Headset System
4. Cleaning and Maintaining DSI-24 Headset
5. DSI-24 Headset battery recharging and additional capabilities
6. Troubleshooting Guide

2.1 Related Manuals

These other manuals are available for Wearable *Sensing*'s hardware and software:

- DSI-Streamer software User Manual

3. 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 below photograph.

The contents of the case include the following components:

DSI-24 Headset for mounting:

- EEG Sensors (with electrodes installed) – 20 sensors total
- EEG Common Mode Follower (CMF)
- Crown section positions sensors in place
- Padded back-piece to facilitate EEG measurements with wearer resting in the supine position
- Forehead Front Strap
- Rear straps between back-piece and temporal segments

Micro-USB cable for wired communication between headset and PC.

Fast USB cable (USB/2.5mm jack).

(included in systems with Internal Memory)

USB- Bluetooth® adapter

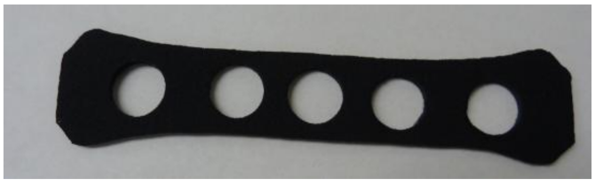
Two Li ion 3.7V batteries
(NB-4L from Energizer, 1200 mA-hr)

Battery Charger

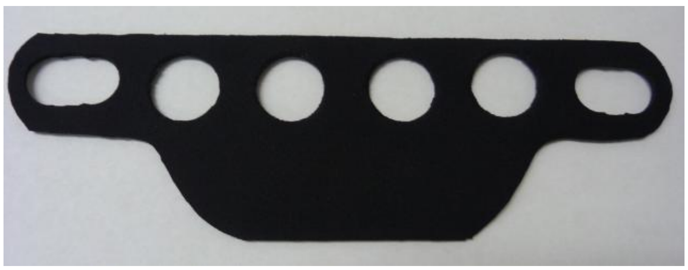
Utility Tool

Spare electrodes (clockwise from top left):

- Inner electrodes with long pins (x17)
- Outer electrodes with long pins (x15)
- Inner flat electrodes (x5)



Spare forehead strap foam pad



Spare rear foam pad

Spare inner foam pad (to be placed under crown piece)

- Two spare pads are included.
- The two pads are different thicknesses – choose thickness that best suits each subject.

USB drive containing DSI-Streamer data acquisition software, drivers and PDF versions of the User Manuals.

Measuring Tape

Battery operated cleaning brush

Bottle for cleaning fluid

Trigger cable

The DSI-Streamer software (supplied on USB drive) requires a PC with Windows XP/Windows Vista/Windows7/Windows 8.

3.1 Additional Components (Available Separately)

A. Sensor Components

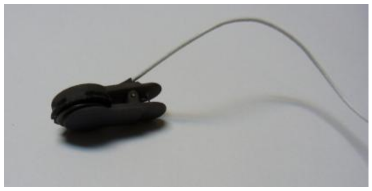
Also available from Wearable *Sensing* are additional sensors that enhance the measurement capabilities for the DSI-24 EEG system. Up to 3 of the sensor configurations in the Table below can be plugged into the external inputs on the DSI-24 headset. The sensors are suitable for the following measurements:

- EEG
- EOG
- ECG
- EMG

The external inputs on the DSI-24 headset are configured prior to shipping. Each input can be set to the following:

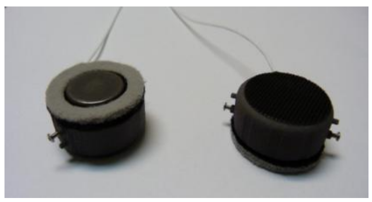
- (M) Monopolar – for use with single sensor cable (e.g. EEG, EOG, EMG)
- (B) Bipolar – for use with dual sensor cable (e.g. ECG, EMG, HEOG, VEOG)
- (L) Linked – for use with dual sensor cable (e.g. linked-ear/lined mastoid reference)

The sensor options are summarized below:



Earclip sensor

Flat sensor (no spring)



Flat sensor (with spring)

- The spring provides isolation from motion artifact by providing constant contact pressure on the electrode

EEG sensor (with spring & outer housing)

- Sensor uses electrodes with pins for getting through hair.
- Sensor has spring to provide isolation from motion artifact
- Outer housing includes additional spring for greater isolation of inner sensor

Elastic straps

- Straps for forearm EMG (top)
- Chest strap for ECG (bottom)

The sensors use identical electronics; only the mechanical design is different between each sensor design.

A. Wireless Trigger Hub

For data synchronization and event 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. It is also designed to simplify the process of consolidating multiple trigger sources in order to avoid the inevitable clock drift that arises between different systems during extended measurements. The use of standardized input connectors (BNC connectors, 3.5mm sockets, DB-25 connectors) allows a wide range of devices to be connected to the Trigger Hub without the need to buy specialized cables.

In addition, the Trigger Hub system has the ability to generate synchronization pulses or to distribute triggers received from multiple sources to multiple devices via its various output connectors. In this way, a multiple triggers source can provide triggers to multiple acquisition systems, allowing the use of trigger events for time synchronization across systems.

Of course, the Wireless Trigger Hub can also send its Output signals Wirelessly to DSI systems!

The Wireless Trigger Hub is sold separately.

4. Getting Ready for Data Collection with the DSI-24 SI Headset

This Section describes the procedure for setting up the DSI-24 EEG system to acquire data. The DSI-24 EEG system transmits data via Bluetooth® or a wired micro-USB cable to a PC.

The following sections describe:

4.1. Putting on DSI-24

4.2. Connecting Hardware

4.3 Inspecting EEG Signal Quality

4.4. Evaluating Physiological Signal Quality

4.5 Other Artifacts

4.6 Removing the DSI-24 System

4.1 Putting on DSI-24 System

The DSI-24 Headset has been designed for head circumferences ranging from 52-62 cm, respectively. Very large or very small heads will not allow correct sensor positioning or correct sensor loading – ***do not force it***.

The head size of EACH subject must be measured PRIOR to donning headset.

A. Measuring Head Size

The headset fitting range can be determined by measuring head circumference and elongation.

Figure 1. Measuring circumference.

Circumference (Figure 1):

- Measure the **circumference** by running a tape measure from the center of the forehead, just above the eyebrows, past the tops of the ears and then around the most rearward point at the back of the skull.
- **The circumference range is 20.5” to 24.4”(52 to 62 cm).**

Figure 2. Measuring elongation.

Elongation (Figure 2):

- The **elongation** of the head is determined by measuring from ear hole to ear hole over the highest point on the top of the head.

If a patient reports discomfort from the headset, seek to locate the source and make adjustments until the patient is comfortable.

If subject's head is smaller than the listed recommendations, the headset may not fit properly and EEG signal quality may be compromised by poor contact between sensors and scalp and/or motion artifacts due to shifting of the headset on the head.

If the subject's head is larger than these recommendations, the headset may not fit properly, and if forced could lead to damage to the sensors, headset, or discomfort to the wearer.

Differently shaped heads or bulges should also be considered when measuring the head and fitting the headset.

DO NOT keep a headset on a patient who reports pain that cannot be alleviated.

B. Locating C_Z and F_Z Sensor Locations on Head

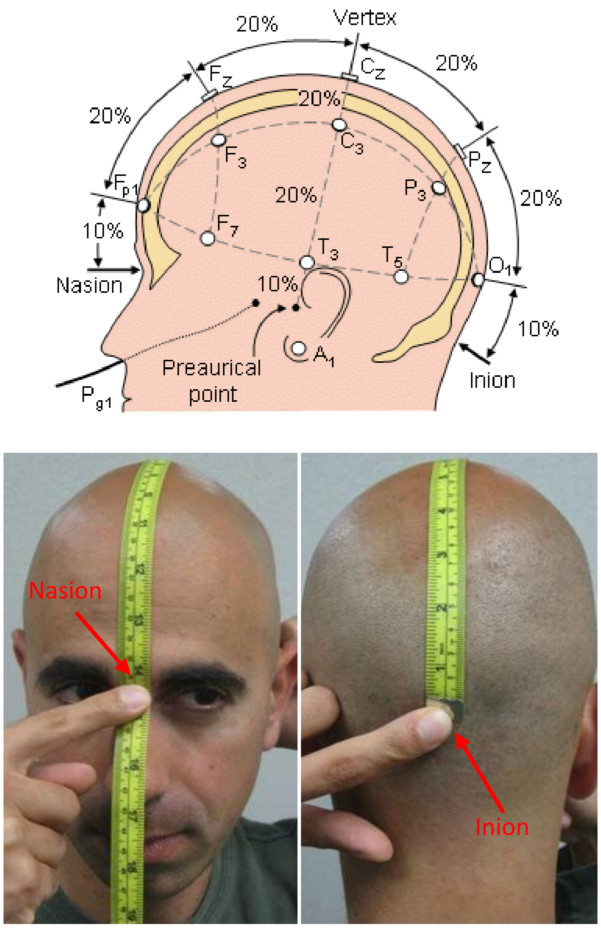


Figure 3. How to locate and measure the nasion, inion and Cz positions on the head.

The crown piece is correctly oriented by accurately positioning the C_Z sensor.

C_Z is situated as shown in Figure 3, exactly halfway between the nasion and inion points.

- The **inion** is the bony bulge located at the most rearward part of the skull, just above the point where the skull sits on the spinal column.
- The **nasion** is the depression between the eyes, just above the nose bridge.

As a guide, the median nasion-inion distance for the adult population is about 38 cm (15”), with a range of 35-41 cm (13.8-16.2”) for 80% of the population.

- Using a flexible tape measure the distance from the nasion to C_Z (see Figure 3).

Figure 4. Distance between nasion and front edge of Fz sensor marked by red line.

Use the formula below to calculate the distance between the nasion and the front edge of the F_Z sensor

- **0.5 x (nasion-inion) - 9.3 (in cm)**.
- **0.5 x (nasion-inion) - 3.7 (in inches)**.

With a little experience it is easy to place F_Z within this limit by eye when viewing the subject from the front (Figure 4).

However, if the subject is anticipated to perform repeated trials then consistent measured placement of the crown piece is preferred.

C. Donning Procedure

The DSI-24 system has sensors at the nominal Fp1, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, P4, T6, O1, O2, M1, and M2 positions of the International 10/20 System. An additional reference sensor (CMF) is placed at the nominal Pz position.

The following steps outline the procedure for donning the DSI-24 system.

Step 1: Visual Inspection of Headset & Sensors

System with mastoid sensors.

System with earclip sensors.

Figure 5. DSI-24 systems.

Visually inspect electrode surfaces (System with earclip sensors.

Figure 5).

- Check for obvious concerns, such as loose or damaged electrodes.
- If needed, follow the cleaning instructions in Section 5.
  (In practice, cleaning should be performed after each subject.)

Step 2: Adjust Headset Size

Figure 6. Rear adjustment for DSI-24 system.

Rotate rear adjustment to extend rear strap to allow for easy donning (Figure 6).

- Extension is achieved by turning rear knob ***counter-clockwise***.

Step 3: Don DSI-24 Headset

Figure 7. Donning procedure for DSI-24.

Position headset above and slightly behind the head, tilted slightly upwards in the front as shown in Figure 7 (left).

- Hold mastoid sensors away from head during donning (in Figure 7, right).
- Pull headset onto head from back to front.

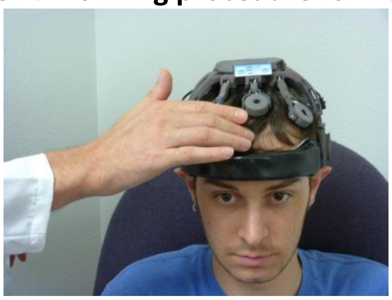


Figure 8. Positioning front strap of DSI-24.

Pull down headset until it sits on the head with the forehead strap against the forehead (Figure 8).

- Ensure that **NO** hair is beneath the forehead strap. The electrodes on the strap are not designed to work through hair.

Figure 9. Making contact between scalp and electrodes on the crown piece of DSI-24 system.

Press down on crown section of headset, until it makes contact with the scalp (Figure 9).

Step 4: Adjust Tension for DSI-24 Headset

Figure 10. Tension adjustment for DSI-24 system.

If crown section is not making adequate contact with scalp, increase tension on elastic (Figure 10).

- Multiple adjustments are available. Take care to ensure that the force on the crown piece is symmetric.

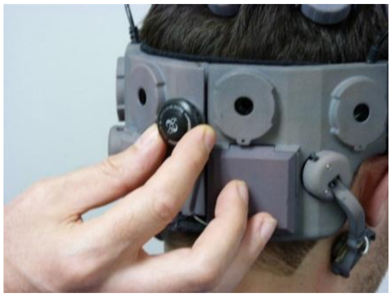


Figure 11. Tightening rear straps of DSI-24 system.

Rotate knob ***clockwise*** to tighten headset from back (Figure 11).

- This adjustment tensions both the rear and front of the headset.
- *The headset should fit snugly, but comfortably. It should neither slide around nor feel uncomfortably tight.*

Step 5: Adjust Sensor Positions – Crown Piece

Figure 12. Routing tubes for elastic that holds crown piece against scalp.

Ensure that the C3 and C4 sensors are not against the routing tubes (Figure 12).

- If so, then move the crown, or the arms, until the sensors are clear.
- Routing tubes conduct the elastic bands that hold the crown to the headband of the headset.

Figure 13. Adjustment of T3, T4 sensors.

Adjustment of T3, T4 sensors

- Adjust T3 sensor backwards or forwards until the indication mark above the T3 sensor is aligned with the subject's earhole (Figure 14).
- Repeat for T4 sensor.

Figure 14. Central line alignment of DSI-24 system.

Central line alignment

- Note that the crown piece moves with the T3, T4 sensors. This is responsible for the majority of front/rear motion of the crown piece.
- In Figure 13, the C4 sensor was not aligned with the T4 sensor.
- Fine positioning is achieved by manipulating the crown piece itself forward or backwards to align the C3, Cz, C4 sensors along the subject's central line, as in Figure 14.

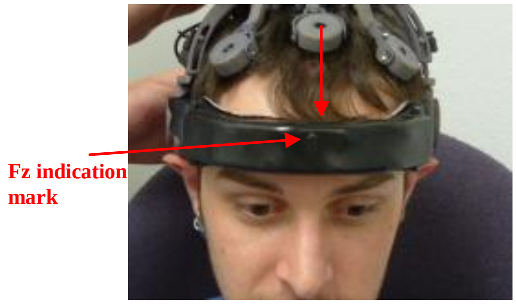


Figure 15. Midline alignment of DSI-24 system.

Midline alignment

- Shift crown piece left/right to align Fz with arrow on front strap (Figure 15).
- This will ensure that the midline electrodes (Fz, Cz, Pz) are located along the subject's midline.
- *Check the central line alignment after this adjustment to confirm that crown piece is still correctly positioned.*

Step 6: Adjust Sensor Positions – Mastoid Sensors / Earclip Sensors

Figure 16. Positioning temporal support segment of DSI-24 system.

For systems with mastoid sensors:

- Rotate sensor arm to locate sensor on the mastoid (Figure 16).
- Rotate the sensor so the flat surface of the electrode is against the skin.

Figure 17. Attaching earclip sensor.

For systems with earclip sensors:

- Unclip sensor from rear of headset (Figure 16). There is one for each ear.
- Unspool enough length of cable for sensor to reach ear.
- Attach to earlobe.

Step 7: Work Sensors Through Hair

Figure 18. Use utility tool to work sensor through the subject's hair.

- Move hair to prevent excessive bunching beneath sensors.
- Insert the utility tool into the matching cutout in the top board of each sensor pod (Figure 18).

Figure 19. Take care to ensure that the sensor does not lift up from the scalp as the utility is removed.

- Rotate the sensor back and forth a few times, first quickly and lightly, then more slowly with slightly more force to ensure contact of the electrode tips with the scalp.
    - The maximum range of motion is ±45°.
- Hold sensor pod down with fingers while you remove utility tool to prevent sensor from lifting off the scalp with the tool (Figure 19).

It is important to hold the sensor down while removing the rotating tool to ensure good contact is maintained. Otherwise the sensor may pull back from the scalp when the tool is removed.

D. Placement of External Sensors

The DSI-24 system has 3 external inputs for additional sensors that can be used for measurements of EEG, EOG, ECG and/or EMG that supplement the measurements from the sensors at the International 10/20 electrode locations.

The following steps outline the procedure for placing the external sensors.

Step 3: Visual Inspection of Sensors

Figure 20. External sensors.

Visually inspect electrode surfaces (Figure 20).

- If needed, follow the cleaning instructions in Section 5.
  (In practice, cleaning should be performed after each subject.)

Step 4: Affix Sensors to Strap

Figure 21. Sensors affixed to strap.

For spring-loaded sensors:

- Spring-loaded sensors have Velcro on their back to attach to Velcro on the strap.
- Position sensors at desired spacing and attach to Velcro strap (Figure 21)

Step 3: Position Sensors

Figure 22. Earclip sensor.

For earclip sensors, attach sensors to earlobes.

Figure 23. (top) Strap for ECG measurements. (bottom) Straps for EMG measurements.

For non-earclip sensors, use strap to hold sensors against the body.

Position sensors at desired location.

- In Figure 23 (top), this corresponds to the strap/ECG sensors placed at the correct height around the chest, and aligned to measure a vector across the heart.
- In Figure 23 (bottom left), this corresponds to the strap/EMG sensors placed at the correct location on the forearm.
- In Figure 23 (bottom right), this corresponds to the two EMG straps placed at two separate locations on the forearm.

Fasten strap.

Step 6: Connect External Sensors

Figure 24. Micro USB connections on rear of DSI-24 headset.

Plug in sensor cables into external inputs

- External inputs are found on the rear of the DSI-24 headset, to the left (Figure 24).
- Configuration of the external inputs are set by Wearable *Sensing* (M, B, or L, as per customer request) prior to shipping.

If headset is configured with multiple modes (M, B and/or L), ensure that sensors are connected to the correct input.

4.2 Connecting Hardware

A. Wired Connection

Step 8: Connect micro-USB Cable to DSI-24 System ***(Wired Communication Only)***

Figure 25. Connection of micro-USB cable to crown piece.

Plug the micro-USB cable into the micro-USB port on the crown piece (Figure 25).

- Plug the other end of the micro-USB cable into a USB port on a PC.

Step 9: Power-Up DSI-24 System

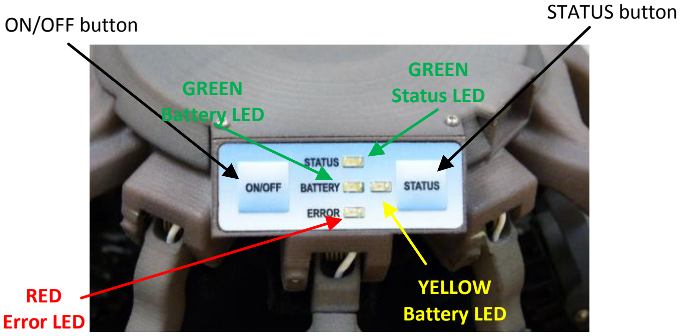


Figure 26. Front panel of DSI-24 system.

Press the **ON/OFF** button twice on the front panel within 2 seconds to turn on DSI-24 system (Figure 26).

- This will make the DSI-24 system seek a BlueTooth® connection, if a paired BlueTooth® device is available.
- 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 (refer to Section 5.4 for details).

Step 10: Establish Communication Between DSI-24 System & PC

There are two steps for establishing communication to your DSI-24 system.

- 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 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 instructions.

B. Wireless Connection

Step 8: Plug in Bluetooth *(Wireless Communication Only)*

Plug the USB-BlueTooth® adapter (Figure 27) into a USB port on the PC that will be used for data acquisition.

- The first time the BlueTooth® module is plugged in to the computer, the computer will begin a procedure to automatically install the drivers for the BlueTooth® device.
- If the computer you are using has built-in BlueTooth®, or are using a different module for BlueTooth® communications, then the drivers will already have been installed on your computer.

Figure 27. USB-Bluetooth® adapter.

Step 9: Power-Up DSI-24 System

Press the **POWER/STATUS** button twice on the front panel within 2 seconds to turn on DSI-24 system (Figure 28).

- This will make the DSI-24 system seek a BlueTooth® connection, if a paired BlueTooth® device is available.
- The **GREEN Status** LED will flash twice to indicate that system is turned on.
- One or more of the battery LEDs will light up indicating the current battery level (refer to Section 5.4 for details).

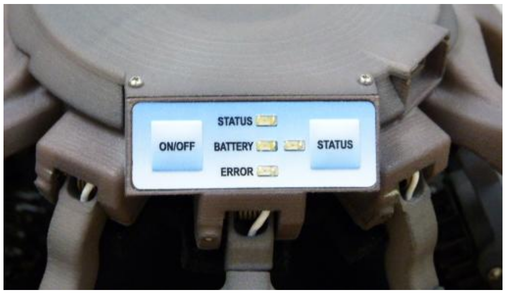


Figure 28. Front panel of DSI-24 system.

Step 10: Establish Communication Between DSI-24 System & PC via BlueTooth®

There are two steps for establishing communication to your DSI-24 system.

- The first time you try to connect, add the DSI-24 system as a new Bluetooth device.
- Each time thereafter, you must use the DSI-Streamer software to establish Bluetooth communication between the PC and the DSI-24 system.
- Refer to the DSI-Streamer software User Manual for details of these two steps.

4.3 Inspecting EEG Signal Quality

Data acquisition is performed using Wearable *Sensing*'s DSI-Streamer software. In total, there are 24 channels of acquisition:

- 20 channels of EEG @ 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 (plus either M1, M2 or A1, A2). Signals in DSI-Streamer are labeled according to electrode location.
- 3 external inputs, which appear as X1, X2 and X3 in DSI-Streamer.
- 1 common-mode (CM) channel, which shows the level of common-mode signals appearing on the body.

Step 11: Inspect Signal Quality

Signal quality is established in two steps:

- Monitor the contact impedance of the sensors.
- Monitor the observed signal levels from the sensors.

Refer to the DSI-Streamer software User Manual for using the Diagnostic tab to assist in establishing that the sensors are operating correctly.

Sensor Contact Impedance

The contact impedance between an electrode and the skin is measured to control the quality of contact. (Since the DSI sensors operate through hair, the contact is not as obvious as on bare skin.) The EEG sensor and CMF reference sensor contact impedances are monitored continuously by out-of-band sinusoidal signals.

Sensor impedances will gradually go down in the first 1-5 minutes after being placed in the scalp.

- For proper operation of the sensors:
  Impedances should be < 1 MΩ

Note that for time-domain analysis of saved EEG data, it is recommended that the impedance signals should be filtered out using notch filters at the impedance drive frequencies. These are 110 Hz and 130 Hz for the sensor & CMF impedance signals, respectively.

Sensor Signal Level

It is generally observed that during the first 1-5 minutes the signal level also decreases.

- For proper operation of the sensors:
  Signal Level should be < 15 µVrms
- Note that we use the term "Signal Level" even though excess voltage levels are indicative of contact noise. We do this because a typical Eyes Open EEG signal (i.e. no excess alpha or beta contributions) has the appearance of broadband noise.
  When the signal level is less than 15 µVrms, the signal is predominantly EEG.

In the event that the contact impedance and the signal level are not below the recommended values, it may be necessary to manipulate the sensors, as per Step 7.

Baseline Reset

Manipulation of the sensors frequently results in transients or saturation of the sensor amplifiers. Under saturation there is no response to the impedance control. For this reason, the DSI-24 system is equipped with a Baseline Reset function that momentarily increases the corner frequency of each sensor's high-pass filter to ≈15 Hz. This facilitates a rapid return to equilibrium after the transient.

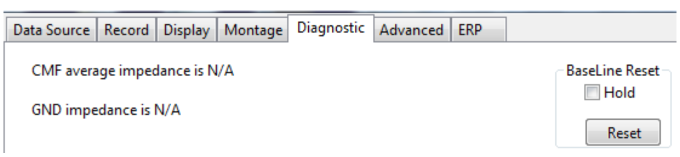


Figure 29. Diagnostic tab from DSI-Streamer software.

In the **Diagnostic** tab in the main window of the DSI-Streamer software is a **Baseline Reset** option (Figure 29)

- Click the **Reset** button to turn on the Baseline Reset function.
  - Reset function is active for 1 second.
- Check the **Hold** checkbox to hold the Reset function active indefinitely the next time the **Reset** button is clicked.
  - While the Reset function is active, unclick the **Hold** checkbox and click the **Reset** button to turn off Reset.

The EEG signal while the Reset function is active is strongly distorted due to the high value of the high pass corner frequency. However, the impedance values are almost immediately correct once the Reset function has been activated.

Refer to the DSI-Streamer software User Manual for further details about using the Diagnostic tab in the DSI-Streamer interface.

4.4 Evaluating Physiological Signal Quality

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.

In the examples below, only electrodes at the International 10/20 locations are shown.

Step 12: Normal Waking EEG

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 in Figure 30.

The bottom channel is the CMF, which measures the common-mode signals that are removed from the other 6 channels.

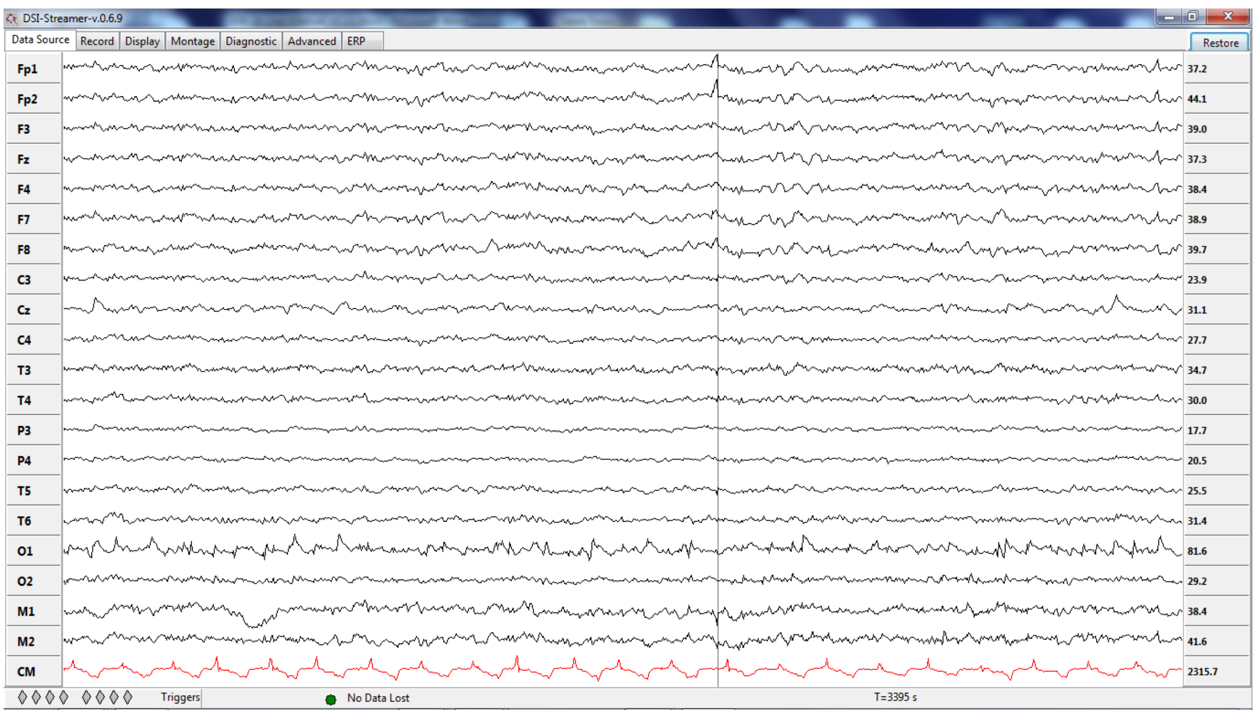


Figure 30. Screen capture of normal waking EEG.

Step 13: **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.

In order 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 Figure 31, which shows two alpha spindles in the center of the screen. Note that since not all patients 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.

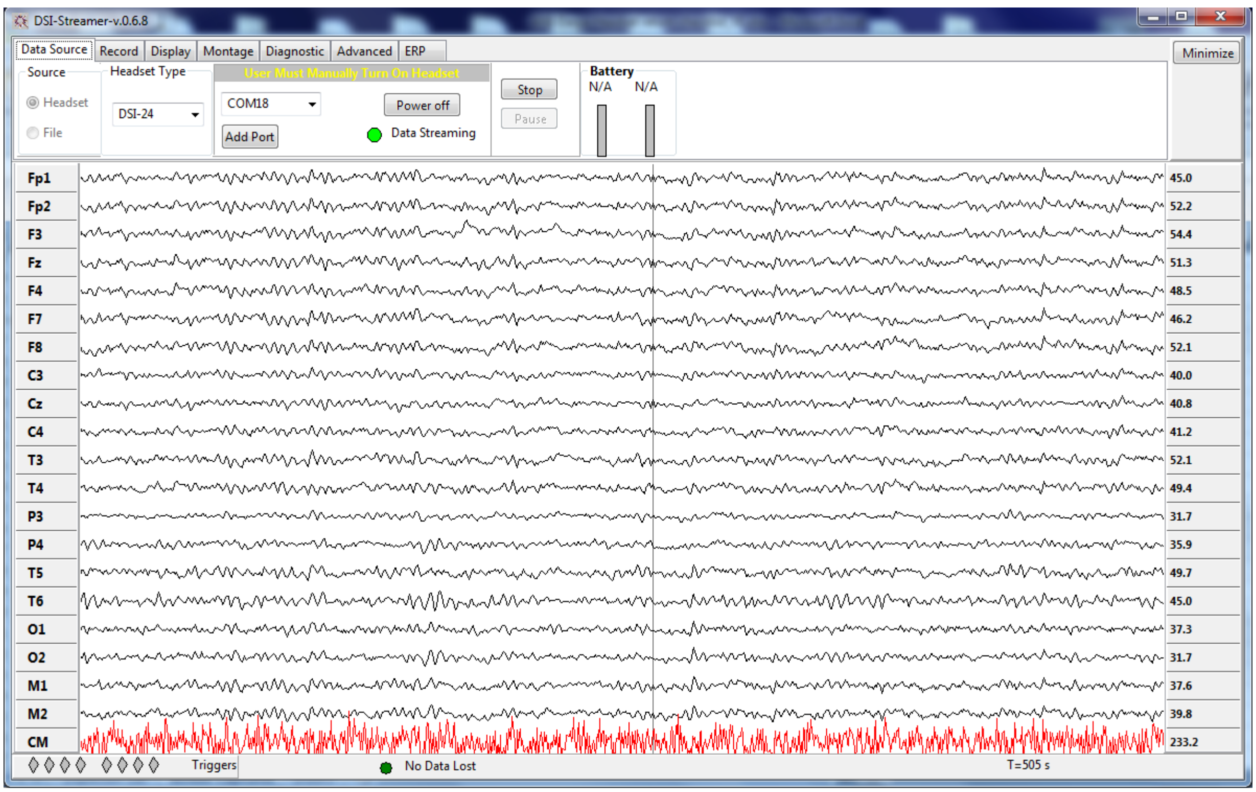


Figure 31. Screen capture of alpha activity during an Eyes Closed measurement.

Step 14: Eye Blink Artifacts

Eye blinks generate a large potential, especially on Frontal sensors (F3, Fz, F4, F7, Fp1, Fp2, F8) when the CMF is placed on the posterior section of the head. The sensors in which eye blinks are most visible are those for which there is affront-back vector between the sensor and CMF.

The representative screenshot in Figure 32 shows rapid eye-blinks in the frontal sensors. Subjects should be instructed to blink rapidly to produce such signals.

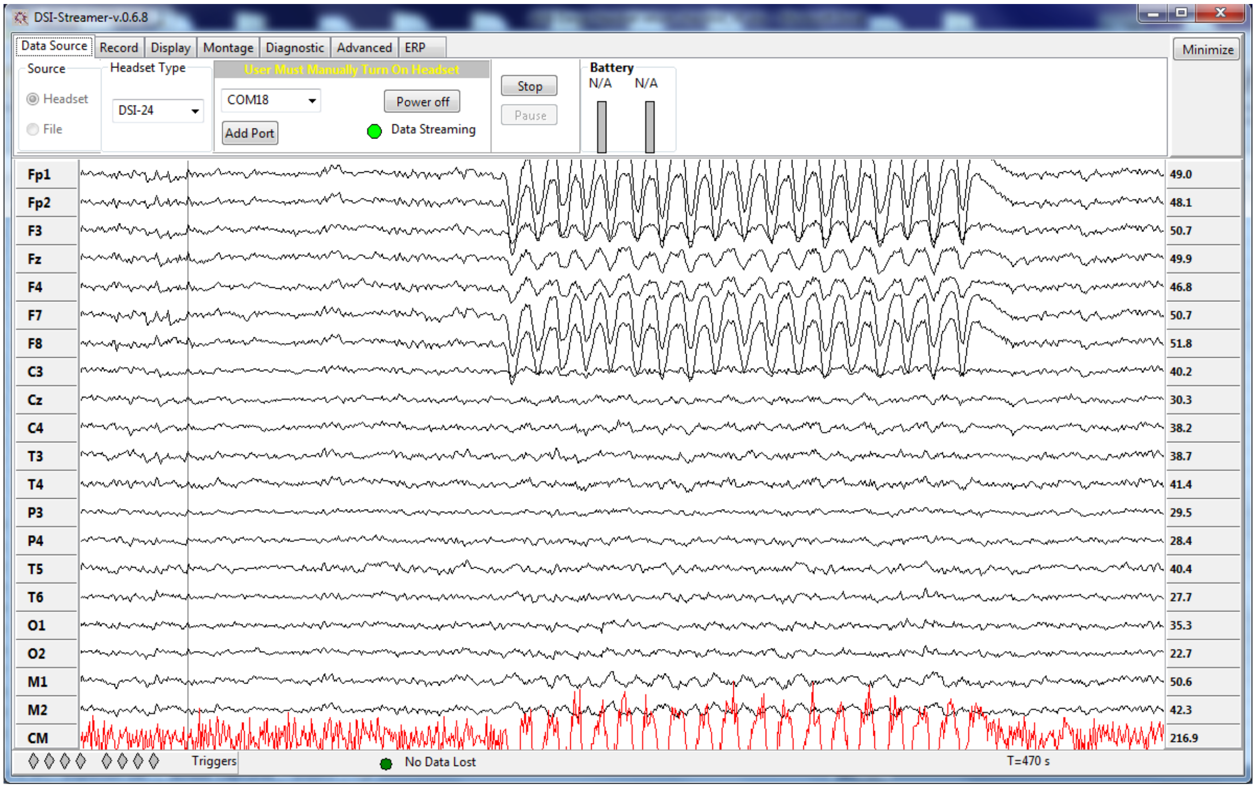


Figure 32. Screen capture of blink artifact.

Step 15: Jaw Clench Artifacts

Jaw clenches generate a large electromyographic (EMG) potential on all electrodes, with the least contribution on Cz (with the CMF also placed away from the jaw muscles).

The transients at the beginning and end of the jaw clench artifact visible in the screenshot in Figure 33 are commonly seen in electrodes close to T3 or T4, where the masseter muscle rises to the zygomatic arch.

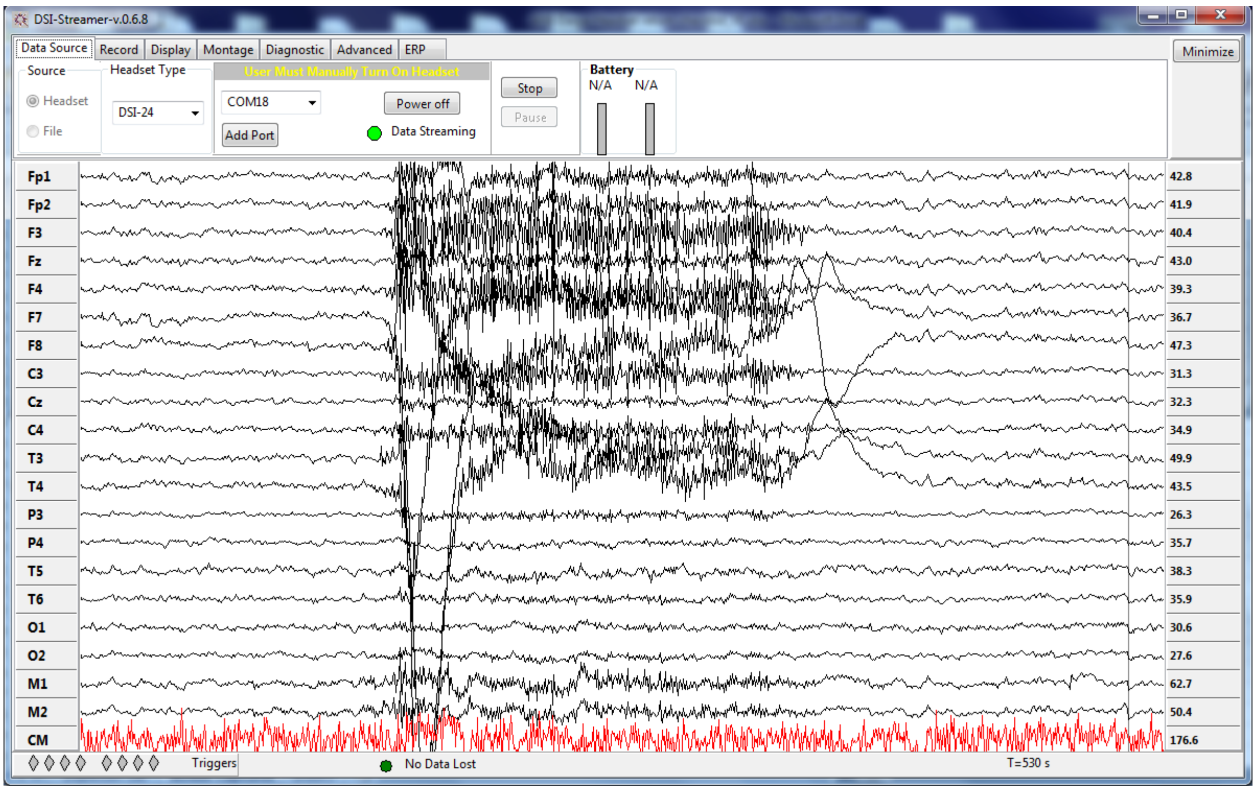


Figure 33. Screen capture of jaw clench EMG.

4.5 Other Artifacts

The signals and artifacts described above are to be expected as part of EEG measurements. The artifacts described below can be minimized during the setup procedure.

Step 16: Pulse, Motion, and Common Mode (CM) Artifacts

Pulse Artifact

Pulse artifacts 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 not making good contact with the scalp or with sensors that are directly over a blood vessel.

The solution is to move the affected sensor 1-2 mm to one side and/or work it through the hair and wait for the artifact to fade. On occasion, the artifact can disappear without intervention by the experimenter, but this cannot be relied upon.

Motion Artifacts

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.

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.

In order to evaluate 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.

Note that during these motion tests the patient should refrain from blinking to prevent blink artifacts from being interpreted as 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.

Common-Mode (CM) Artifacts

Common -mode (CM) artifacts are large interfering signals detected by an EEG sensor due to voltages appearing on the body. These can either be due to triboelectric charging of the subject produced by the subject's motion (e.g. walking, sitting or standing up from a chair) or via pickup of a nearby electric field (e.g. tribelectrically charged person walking nearby, mains pickup).[1] The CMF is utilized to dynamically remove CM artifacts from the input of the sensors. The degree of rejection of CM artifacts between sensors is often determined by the quality of the electrical contact to the scalp (low contact impedance implies good rejection of CM artifact).

It is recommended that in order to evaluate the level of CM artifacts, the CM signal due to tapping a foot should be measured. In order to isolate this effect from motion artifact, the operator should stamp their foot whilst being maintaining good electrical contact with the subject (e.g. holding a hand of the subject), and monitor the EEG trace to look for the presence of CM artifacts (or absence thereof) such as the ones illustrated in Figure 34.

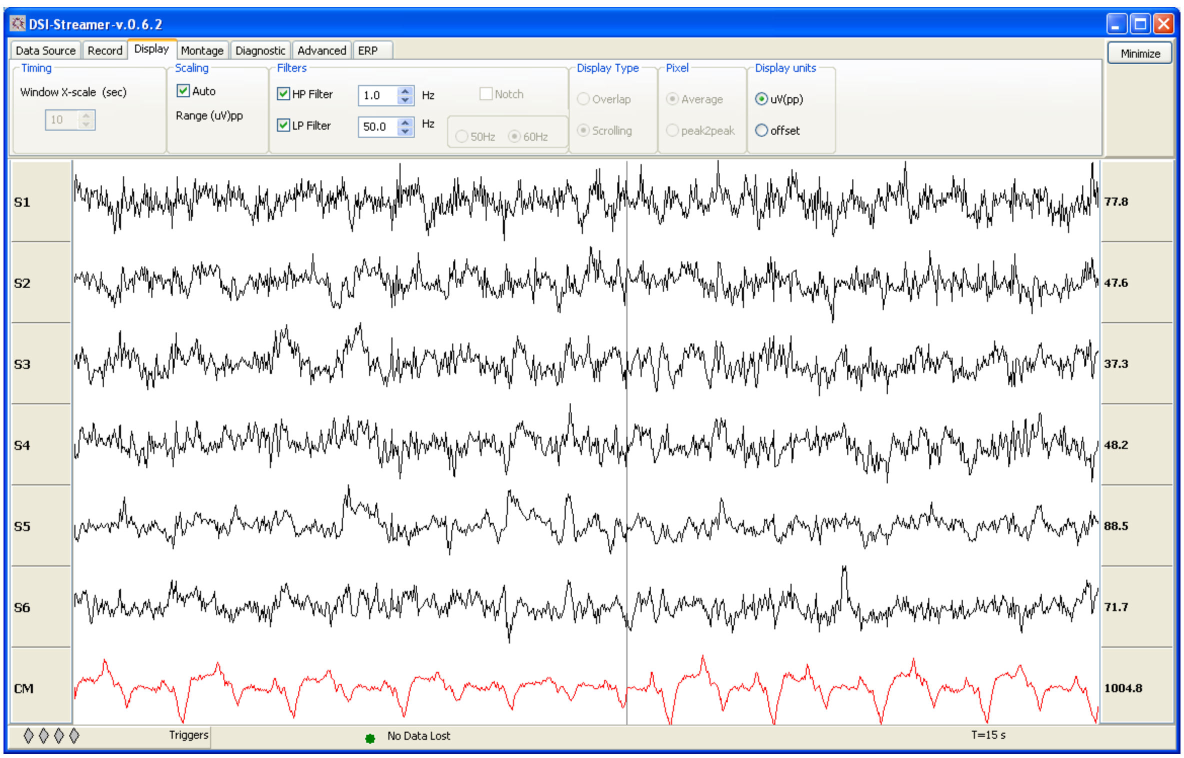


Figure 34. Screen capture of CM artifact during tapping.
Note the lack of visible motion artifact in the EEG channels.

[1] Wearable Sensing's EEG sensors are essentially high-sensitivity, high-impedance antennae, and are consequently very sensitive to the common mode (CM) electric field appearing on the body. A person walking nearby may possess an electric potential many thousands of volts relative to the subject due to triboelectric charging (consider the electric shock experienced when touching metal in a dry environment), and this potential couples capacitively to the subject, causing the voltage appearing on the subject to change as the other person walks by. Wearable Sensing's EEG systems have strong protection from this type of electric fields. This is usually at the level of 60-80 dB.

Note that when the system is operating correctly, the artifacts should appear on the CMF channel, but should not appear on any of the sensor channels.[2] Sensors that show CM artifact should be worked further through the hair and waited upon to settle further.

If most of the sensors show artifacts with a similar pattern, as shown in the screen shot below, then it is likely that it is the CMF sensor that is not making proper contact, and should be worked further through the hair and waited upon to settle further.

[2] If motion artifacts do not appear in the CM channel, there is not enough charge pumped in the body and one cannot judge the level of CM mitigation. In this case the operator should stomp stronger and/or stomp on material that is opposite in the triboelectric series to the material of the sole of the operator's shoe/foot (e.g. skin – Teflon, rubber – Nylon).

4.6 Removing the DSI-24 System

Step 17: Turn Off DSI-24 System

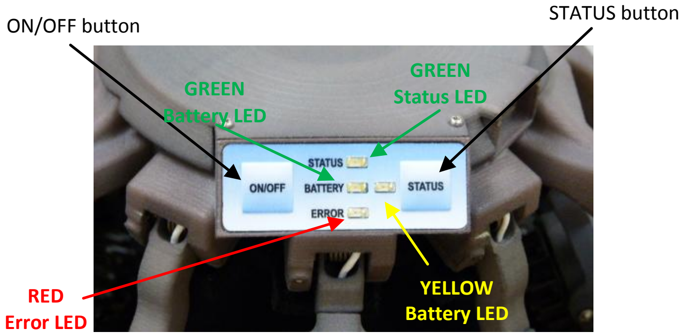


Figure 35. Front panel of DSI-24 system.

Press and hold the **ON/OFF** button on the electronics package for about six seconds to turn off the DSI-24 system (Figure 35).

- Rapid flashing of the **GREEN Status** and **RED Error** LEDs indicates that the system is OFF.

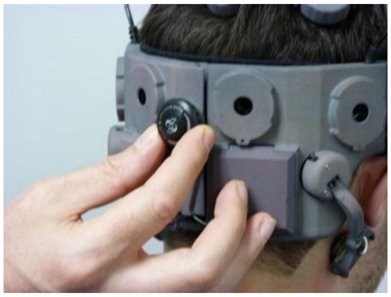


Figure 36. Loosening DSI-24 headset for removal.

- Loosen headset by rotating rear knob ***counter-clockwise*** (Figure 36).
- Clean system as described in Section 6.

5.1 Data Acquisition

Once communication between the DSI-24 system & the PC has been established, data acquisition can be performed using Wearable *Sensing*'s DSI-Streamer software, which has been included with the DSI-24 system.

Data acquisition with Wearable *Sensing*'s EEG hardware has three modes:

- A *data streaming* mode, in which data is passed to the PC and displayed in real time
- A PC *data recording* mode, in which data is passed to the PC and written to disk in real time.
- A headset *data recording* mode, available in some DSI-24 systems equipped with internal memory, in which data is written directly to memory on the headset, even when the headset is out of BlueTooth® range of a computer running acquisition software.

Below is a cursory introduction to starting data acquisition and recording EEG data from the DSI-24 system. Refer to the DSI-Streamer software User Manual for more details.

Using Wearable *Sensing*'s DSI-Streamer Data Acquisition Software

In the **Data Source** tab in the main window (Figure 37), select the **Headset** option under **Source**.

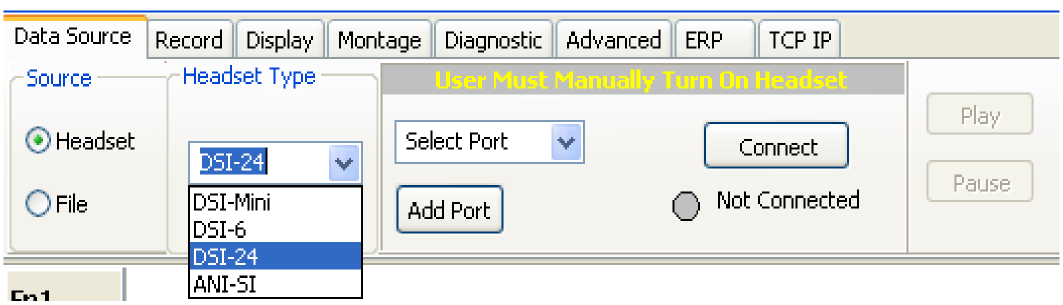


Figure 37. Data Source tab in DSI-Streamer software.

From the drop-down menu under **Headset Type**, choose the "DSI-24" option.

Choose the COM port corresponding to your wired/Bluetooth® connection from the COM port drop-down menu.

- Refer to the DSI-Streamer software User Manual for the procedure to identify the COM ports in use, if not already known.

Press the **Connect** button.

- At this point the **Connect** button will change to **Power off** (see Figure 37).
- At this point the **Play** button will no longer be grayed out.

Press the **Play** button.

- The DSI-24 system is now in *Data Streaming* mode.
- EEG data are displayed in real time.
- In cases of poor BlueTooth® reception, a delay of up to 13 seconds may occur before an event is displayed. This delay corresponds to the DSI-24 system's on-board buffer.

Recording EEG Data

Both data acquisition modes are controlled in the **Record** tab in the main window.

Refer to the DSI-Streamer software User Manual for the procedure for recording data to the PC's hard disk, and the procedures for recording data to and retrieving data from the headset's internal memory.

In both cases, the data can be saved in comma-separated-value (.csv) or European Data Format (.edf) files.

Specific details for the data files written to hard disk using DSI-Streamer can be found in the DSI-Streamer software User Manual.

5.2 Downloading Data From Headset Internal Memory

Download from headset is via the fast USB cable (USB /2.5mm jack).

- Connect the 2.5mm jack to the EEG headset.
- THEN plug the USB connector into the PC running DSI-24 application.

Figure 38. Fast USB input connector on Wearable *Sensing*'s DSI-24 systems.

Do not attempt to connect the headset to the PC while data is being written to the headset's internal memory. This may cause an error that can corrupt previously recorded data and damage the internal memory (requiring replacement of memory components).

5.3 Trigger Inputs

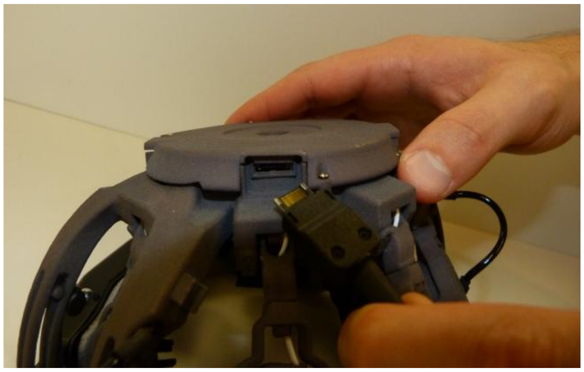


Figure 39. Trigger input connector on Wearable *Sensing*'s DSI-24 systems.

The DSI-24 system supports 8 independent trigger signals.

- The trigger inputs are accessible via the input connector on the input connector of the electronics package (Figure 39).
- The trigger inputs are optically isolated so that connecting triggers to the DSI-24 system does not compromise the isolation from common-mode signals obtained by using wireless communication.

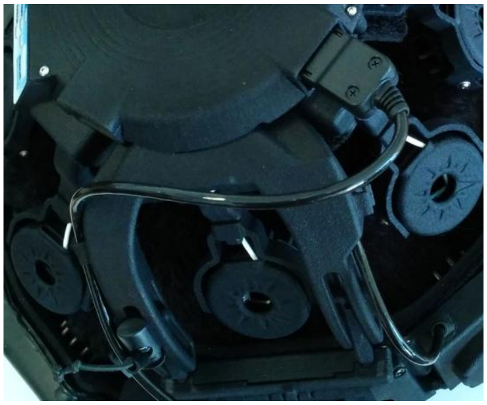


Figure 40. Trigger input connector fastened into strain relief holder.

The Trigger cable should be securely plugged into the Trigger port (Figure 39).

Then the Trigger cable should be fastened to the strain relief holder on the side of the headset as shown in Figure 40.

Figure 41. Trigger Cable.

- The parallel port end of the Trigger cable (Figure 41) should be connected to your trigger source (e.g. PC parallel port) or to the Wireless Trigger Hub Output.

A Wireless Trigger Hub is available separately from Wearable Sensing. The Wireless Trigger Hub supports parallel port, BNC, audio, light, & push button inputs, & up to 8-bit wired, and 1-bit wireless outputs. It includes one photodetector, and one push button.

Refer to the Trigger Module User Manual for specifications of the trigger signal requirements.

5.4 DSI-24 System Control Panel Button Commands and LED Responses

The status of the DSI-24 system is indicated by an array of 3 LEDs on the front panel, shown in Figure 42.

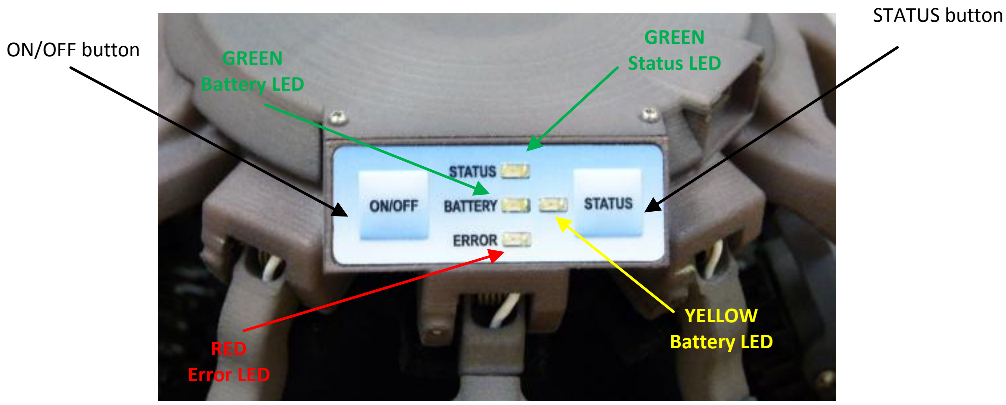


Figure 42. Front panel of DSI-24 system.

The specific functions indicated by the LEDs are summarized in the Table below.

Function	**Action on the Button**		**LED Response**				**State**
	ON/OFF	**STATUS**	***GREEN Status LED***	***RED Error LED***	***GREEN Battery LED***	***YELLOW Battery LED***	
Turn DSI-24 Headset **ON**	Double Press		Twice	-	Once	-	DSI-24 system **ON**
QUERY of Power Status		Single Press	-	-	-	-	DSI-24 is **OFF**
			Twice	-	-	-	DSI-24 is **ON**
Turn DSI-24 Headset **OFF**	Press and hold for ≈ 6 sec		Rapid Flash	Rapid Flash	-	-	DSI-24 system **OFF**
QUERY Status of Data Acquisition (DAQ)		Single Press	Once	-	-	-	DAQ is **OFF** (Idle state)
			Twice	-	-	-	DAQ is **ON**
QUERY Battery Charge		Single Press	-	-	Once	-	> 95% battery life (High)
			-	-	Once	Once	30-95% battery life (Medium)
			-	-	-	Once	10-30% battery life (Low)
			-	-	-	Flash every 5 seconds	< 10% battery life (Recharge Battery)
Software-Initiated **Low Battery Warning**			-	Once	-	-	< 10% battery life (Recharge Battery)
Unexpected **Alarm**			-	Once	-	-	Use software to identify alarm
Analog Reset for Amplifiers	Single Press		Once	-	-	-	DAQ **OFF**
			Twice	-	-	-	DAQ **ON**

Note: A "Single Press" refers to a single button press shorter than 1 sec, and a "Double Press" is a sequence of two presses separated by less than 0.5 sec.

6. Cleaning and Maintenance of DSI-24 System

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

- Sensor electrodes (inner & outer electrodes)
- Replaceable neoprene foam pads
- Foam support for back-piece

The sensors & replaceable foam pads are shown in Figure 43 and Figure 44, respectively.

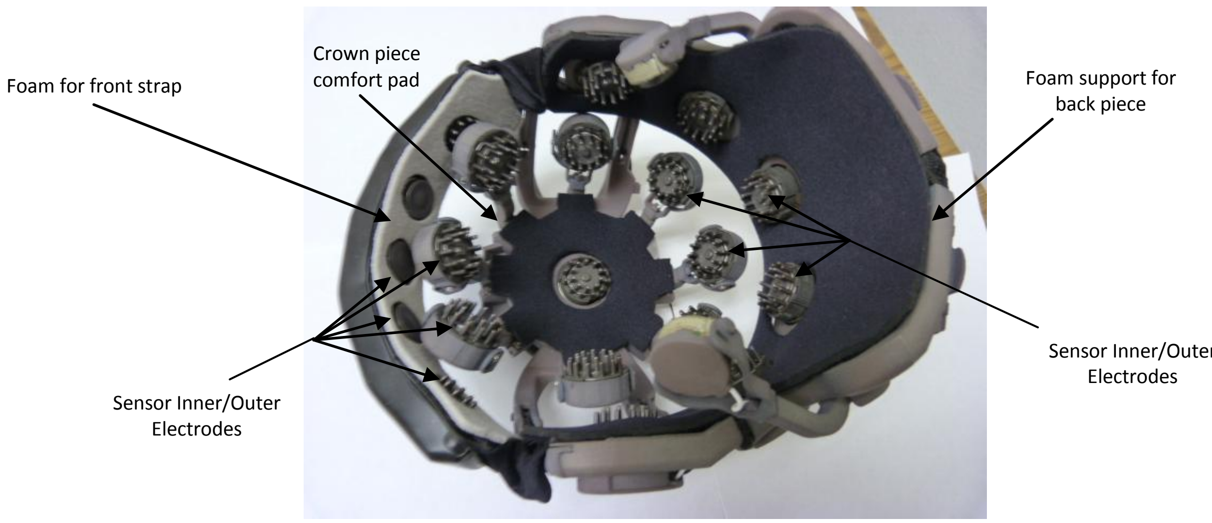


Figure 43. (left) Through-hair EEG sensors. (right) Forehead EEG sensors.

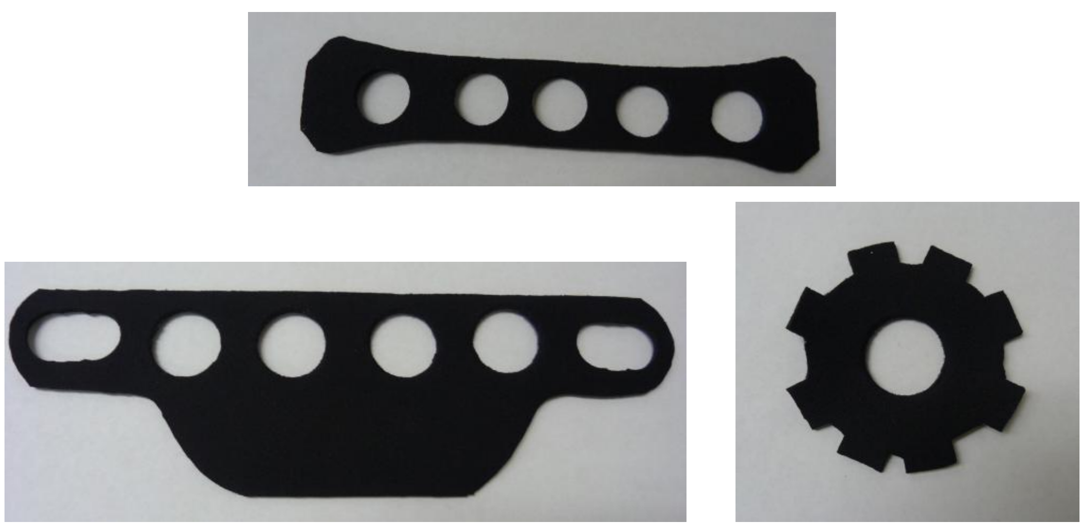


Figure 44. (Clockwise from top left) Foam pad for forehead strap, rear foam pad, and foam pad placed under the crown piece.

6.1 Cleaning Supplies

Recommended cleaning supplies for the DSI-24 system are:

- Battery-operated soft bristle brush (provided with DSI-24 system)
- Cleaning solution – Wearable *Sensing* recommends either
    - 70% Isopropyl Alcohol, or
    - 2% Chlorhexidine

  Either cleaning solution can be stored in bottle provided with DSI-24 system.

6.2 Cleaning Procedure

Figure 45. Pour out a small amount of cleaning fluid for cleaning the electrodes.

- Pour a small amount of cleaning fluid into a container.
- Dip bristles of cleaning brush into cleaning fluid (Figure 45).

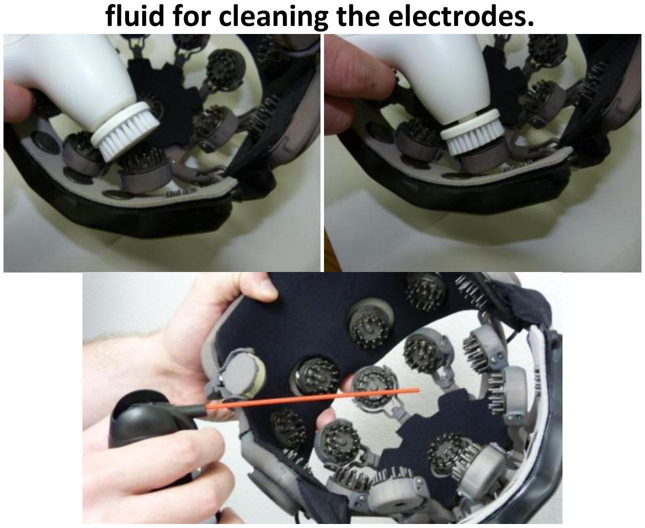


Figure 46. Cleaning procedure for electrodes on EEG sensors.

- Using the soft bristle brush, gently clean the electrodes by applying the cleaning solution to all of the pins.
- Apply brush to pins on both the inner and outer electrodes (Figure 46, top row).
- Repeat for each sensor.
  Allow the sensors to dry completely.
    - The drying process can be expedited using compressed air (Figure 46, bottom).

Figure 47. Storage case for DSI-24 system.

- In order to avoid damage, DSI-24 system should be stored in the case in which it was received (Figure 47).

Dispose of cleaning fluid responsibly.

6.3 Replacing Electrodes

Wearable *Sensing* recommends that the sensor electrodes should be replaced after 25 uses. 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.

The procedure for replacing electrodes is presented below.

Replacing Inner Electrodes

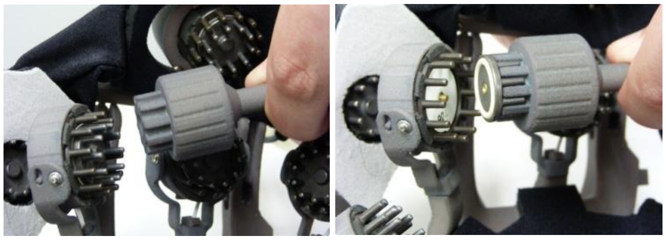


Figure 48. Removing Inner Electrode using the utility tool provided.

Removing Inner Electrodes:

- Unscrew electrode tips by rotating them counter clockwise using utility tool (Figure 48).

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.

Figure 49. Attaching Inner Electrode using the utility tool provided.

Attaching Inner Electrodes:

- Screw new electrode tips by rotating them clockwise (Figure 49).
- The inner electrodes come supplied with a neoprene O-ring at the rear. This prevents ingress of moisture to the electrode-sensor contact, thereby avoiding undesired electrochemical effects.
- Ensure O-ring is well compressed, but do not over-tighten sensors.

Over-tightening the electrode can damage the connection on the sensor, rendering the sensor unusable.

Replacing Outer Electrodes

Removing Outer Electrodes:

- Using a pair of tweezers, carefully lever off the Outer Electrode (Figure 50).
- There are indentations around the outer edge of the sensor that give access to the rear of the Outer Electrode.

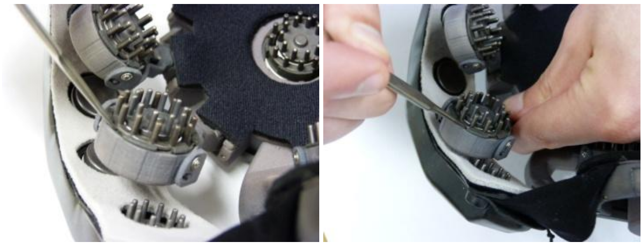


Figure 50. Removing Outer Electrode using a pair of tweezers.

Attaching Outer Electrodes:

- Carefully use your fingers to snap the Outer Electrode back in place (Figure 51).

Figure 51. Attaching Outer Electrode using the utility tool provided.

7. DSI-24 System Battery Recharging

7.1 Recharging the DSI-24 Headset Batteries

The DSI-24 system is supplied with two Li-ion batteries (3.7 V, ERD-150). 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 (Figure 42) 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 – see Section 5.4). Batteries should be charged using the battery charger.

Replace/Recharge One or Both Batteries

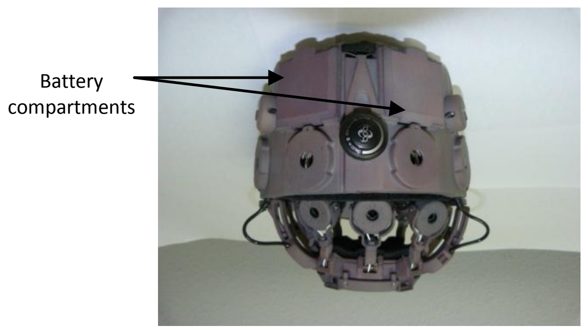


Figure 52. Attaching Battery compartments for the DSI-24 system.

Turn OFF headset as above.

- Open battery compartment(s) (Figure 52).

Figure 53. Removing battery from battery compartment.

Remove battery from the battery compartment (Figure 53).

- Note that the connection terminals for both batteries are towards the center – hence one battery is “upside down” relative to the other.

Figure 54. Removing Recharging battery using

Recharge battery with provided mains battery recharger (Figure 54).

mains battery charger.

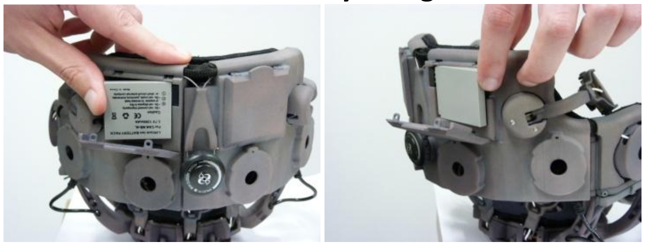


Figure 55. Replacing battery in battery compartment.

Insert battery in the proper orientation (Figure 55).

Close door of battery compartment.

Replacing Batteries Without Stopping Data Acquisition

Figure 56. Removing battery from battery compartment.

This operation can be performed when using two batteries.

- During data acquisition, open one battery compartment.
- Remove battery from the battery compartment (Figure 56).
- System 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.

8. Troubleshooting Guide

8.1 Poor Signal Quality or Unusual Artifacts

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

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

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

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

If data quality continues to be poor, record a segment of data and email it to Wearable Sensing Tech Support.

[3] An impedance equal to 99 MΩ will be reported if no signal is passing though the channel. This can occur when a) there is no connection between the head and the sensor input (bad electrode-to-sensor or electrode-to-head contact), or b) the line is broken. If the problem persists with a replaced electrode, return the headset to Wearable *Sensing* for maintenance.