SmartEP

Software Manual

Intelligent Hearing Systems
Telephone: (305) 668-6102 • Fax: (305) 668-6103
Toll Free: 1-800-IHSYSTEMS (1-800-447-9783)
E-mail: ihsys@ihsys.com
Web: http://www.ihsys.com

SmartEP Software Manual for version 5.54

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Manufacturer:
Intelligent Hearing Systems
6860 SW 81st St.
Miami, FL 33143
USA

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Introduction

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Congratulations on the purchase of Intelligent Hearing Systems (IHS) equipment. To obtain maximum benefit and safety from your system, please be sure to read all the enclosed documentation. If you have any questions as you read these instructions, please contact our customer service department or your local dealer.

Intended use

SmartEP is an evoked response testing and diagnostic device, capable of eliciting, acquiring, and measuring auditory, somatosensory, and vestibular evoked myogenic potential data.

The intended use of the SmartEP device is to objectively record evoked responses from patients of all ages upon the presentation of sensory stimuli. The product is indicated for use as a diagnostic aid and adjunctive tool in sensory related disorders (i.e., auditory, somatosensory, and vestibular). The SmartEP device is for prescription use.

Patient Population

The SmartEP device can be used for patients of all ages, from children to adults, including infants and geriatric patients.

Intended Operator and Operating Environment

The SmartEP device is intended to be used by trained personnel in a hospital, nursery, clinic, audiologist's, EP technologist's, surgeon's, or physician's office, operating room, or other appropriate setting.

Anatomical Sites of Contact

The anatomical sites of contact for auditory evoked potential (AEP) testing are the patient's ear canal (with the contact object being a sound delivery ear tip or headphone, or an ear probe and personal ear tip, or ear cup), the patient's head (with the contact object being a bone vibrator), and the patient's scalp and possibly other body sites (with the contact object being electrodes that are capable of measuring bio-potentials).

The anatomical sites of contact for somatosensory evoked potentials (SSEP) testing are the patient's head or possibly other body sites (with the contact object being electrodes, or metal conductor accessories, which can deliver electrical current), and the patient's scalp and possibly other body sites (with the contact object being electrodes that are capable of measuring bio-potentials)

The anatomical sites of contact for vestibular evoked myogenic potential (VEMP) testing are the patient's ear canal (with the contact object being a sound delivery ear tip or headphone, or an ear probe and personal ear tip, or ear cup) and the patient's head and neck and possibly other body sites (with the contact object being electrodes that are capable of measuring bio-potentials).

Contraindications

- When using acoustic stimuli, an otoscopic examination should be performed to ensure that there are no contraindications to placing a stimulator in the ear canal.
- When providing a high-level acoustic stimulus, care should be taken with subjects with tinnitus, hyperacusis or any other sensitivity to sounds. In all cases the test should be terminated if any signs of discomfort are displayed.
- All methods of sound conduction use magnets, which could affect susceptible programmable devices. Before use in patients with magnetically programmable devices, such as programmable brain pressure drain shunts; consult with the device manufacturer to assess if it is safe to do so.

Software Installation and Requirements

Refer to the instructions for use document corresponding to the hardware platform for your system to:

- Identify the software's Computer Requirements
- Step-by-step instructions for software installation
- Step-by-step instructions for hardware connections

Hardware Manuals

Platform specific manuals can be found in the Manuals folder inside the provided installation media, or in the installation directory once the software is installed. See Reference Documentation on page 10.

Hardware Considerations

The functionality of the software will be dependent on the hardware that is being used in combination with it. The Universal Smart Box (USB Box), USB Jr Duet, Solo, and Universal Smart Box Lite (USBLite) will have different capabilities due to their physical characteristics. For additional technical and regulatory details about each hardware platform, consult their respective reference documentation. See Reference Documentation on page 10.

USB Box:

- Up to 6 or 8 channels of acquisition (Maximum is dependent on the installed hardware options, some channels may be needed for OAE or Somatosensory Modules).
- User-selectable filters, gain, and notch filter.
- Electrode impedance measured using the Opti-Amp Transmitter.
- Can run all modules available to SmartEP, including auditory, somatosensory, and visual potential acquisition.

Duet capabilities within SmartEP:

- 2 channels of acquisition, single channel mode available
- User-selectable filters, gain, and notch filter.
- Electrode Impedance is shown in the Amplifier window inside SmartEP software.
- Can run all auditory modules functionality available to SmartEP, EMG monitoring, and VEMP.

Solo capabilities within SmartEP:

- 1 channel of acquisition.
- Filters and Gain are Hardware-based and may not be changed.
- Notch Filter is always ON.
- Electrode Impedance is shown in the Amplifier window inside SmartEP software.
- It can acquire ABR. Only the base SmartEP functionality is available for this device.

USBLite capabilities within SmartEP:

- 1 channel of acquisition.
- Filters and Gain are Hardware-based and may not be changed.
- Notch Filter is always ON.
- Electrode Impedance is shown in the Amplifier window inside the SmartEP software.
- It can acquire ABR. Limited ECochG and MLR acquisition due to the fixed hardware filters. Only the base SmartEP functionality is available for this device.

Protected Health Information Policy

All files required for system operation and hold Protected Health Information (PHI) are encrypted. To ensure privacy of Protected Health Information (PHI), any data sent to Intelligent Hearing Systems, or any third parties, must be de-identified prior to transmission.

IHS will not accept any information that has not been de-identified from any Sources; in either electronic form (e-mail, fax, etc.) or physical form (computers, hard drives, etc.) PHI includes, but it is not limited to, acquired patient responses and media such as images or video recordings. Any information not meeting these criteria will be destroyed upon receipt.

The owner of the device shall take responsibility for the security of PHI produced while using the software, device, and related components. The following considerations must be considered, and can be implemented by the license owner's:

- Password protection of electronic documents (PDF files) that contain PHI such as medical record forms.
- Deletion of exported text files (ASCII files) that contain PHI immediately after use, such as export lists to patient databases,
- Limiting access to the computer holding the software installation, using access control and password protection as allowed by the operating system features to prevent unintended users from being able to access PHI.

Safety Information

Ensure safe operation by complying with the warnings and cautions as stated in the reference documentation corresponding to the hardware platform being used. See below.

Reference Documentation

Additional information can be found in the Instructions for Use for your respective platform. Please refer to the following documents as appropriate:

- **USB Jr Duet Platform**: Instructions for Use (REF M080014)
- **USB Platform**: Installation Manual (REF M080011) and Technical Reference (REF M080001)
- **Solo Platform**: Installation Manual (REF M080015) and Technical Reference (REF M080005)
- **USBLite platform**: Installation Manual (REF M080013) and Technical Reference (REF M080003)

Information includes, but is not limited to:

- Computer requirements,
- Hardware and Software installation,
- Software setup,
- Symbols used,
- Safety information,
- Cybersecurity,
- Customer responsibility,
- Incident reporting,
- Servicing and Maintenance,
- Warranty statement,
- Equipment classification,
- Technical specifications,

Getting Started

2

Hardware connections

It is highly recommended to verify all hardware connections before turning ON the unit, starting up the SmartEP software, and/or connecting to a patient or subject. The following checklist gives you an outline of the possible connections that should be verified before usage. Not all items in this list apply to every hardware type.

1. Verify the hardware unit power:
   - The USB Power Supply for the USB Box should be connected to an isolation transformer using a medical-grade power cord. The USB power supply should be securely connected to the USB Box using the 5-pin power connector.
   - The Duet can be connected directly to the power mains; it does not require the use of an isolation transformer. However, an isolation transformer is recommended when placed on a cart or desk with a metal structure, to facilitate grounding and simplify plug-in into the power mains.
   - The USB Jr. unit should be connected to an isolation transformer using a medical-grade power cord.
   - The Solo and USBLite units get their power from the USB connection and do not need a power supply; the units only receive power and have their Power LEDs lit up when the computer is ON.
2. If using an isolation transformer, the PC power supply must be connected to the same isolation transformer as the IHS hardware. Use a grounded power strip to connect multiple devices to the transformer if needed. Make sure not to exceed the isolation transformer's rated maximums. All other third-party powered devices, such as printers, which will be connected to the unit must be plugged into the same isolation transformer.
3. If the unit is being placed on a metal structure, such as a cart or rack, it is highly recommended that the metallic components of the structure be grounded. Isolation transformers have a grounding screw that can be used for this purpose. Simply run a conductive cable from the grounding screw to any location on the metal structure.
4. The Opti-Amp transmitter should be connected to the USB Box or USB Jr. boxes using the fiber optic cable, one optical port per AEP channel, and the 3-pronged power cable. The Duet, Solo, and USBLite units do not use optical cables.
5. Connect the IHS hardware to the computer:
   - Connect the USB Box, Duet, USB Jr., or Solo to one of the computer's USB ports using the provided cable.
   - The USBLite unit includes a USB Power Splitter cable; use that cable in between the USBLite and the computer, using both ends of the splitter.
6. Connect the stimulus transducers to be used. Refer to the hardware installation manual for connection details. Some transducers, such as high-frequency transducers will need an additional device to connect to the USB box. Note that some equipment may share a connection with hardware used for other software programs, disconnect those other devices, and connect the ones you will need for SmartEP.
7. Connect the patient cables.
   - The USB Box and USB Jr. use multiple electrode leads attached to the Opti-Amp transmitter unit.
   - The Duet and Solo use a patient cable connected directly to the 6-pin safety electrode connector.
   - The USBLite unit uses a patient cable connected directly to the green Fischer connector.

For additional details about the hardware connections for specific hardware units, refer to their corresponding system installation manual.

System password

Many administrative features in the software may require the use of the global system password. By default, this password is set to 'ihs'. Consult the Launch Pad manual or the hardware's instructions for use manual to learn how to change this password, and to learn about other security features

Starting SmartEP

The SmartEP start button is easily accessible from the Launch Pad program shortcuts. The Launch Pad application should be available from a desktop shortcut, or the Windows Start Menu; refer to the Launch Pad and the Software Installation manuals for additional details. You can also choose to create a shortcut directly to the SmartEP program as follows:

1. Use Windows Explorer to browse your computer's 'C' drive and find the IHS installation folder, by default, the name of this folder is "IHSPROGS".
2. Inside the installation folder, find the program called "SEPWIN.EXE". Use a right-mouse-click over the program to open the context menu. (Keep in mind that depending on local settings, some computers may not show known file extensions like ".EXE"; in that case, the file name would only show as "SEPWIN".)
3. From the context menu, select **[Send to > Desktop]**.
4. Close the explorer window and rename your new desktop icon as needed.

Program layout

The following image shows the general layout of the SmartEP program.

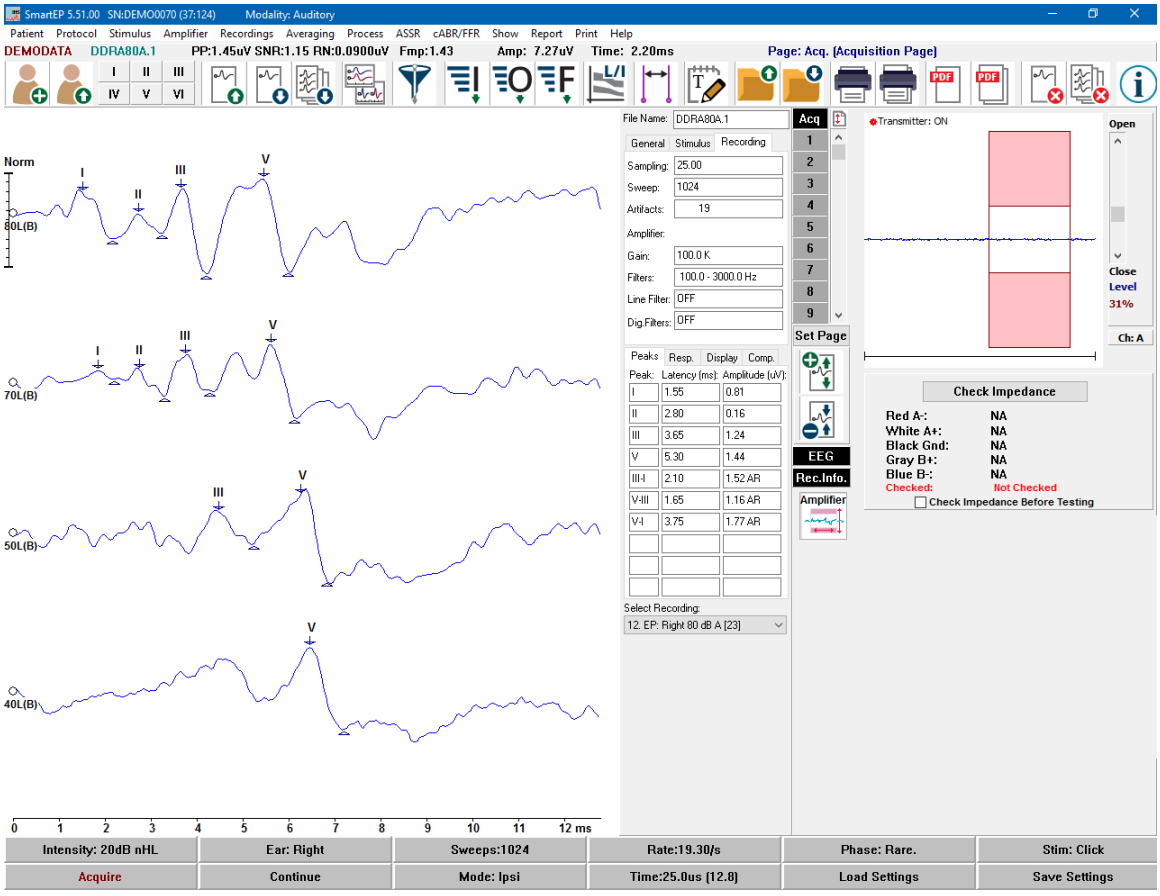

Figure 1 - SmartEP Main Window

The different areas of SmartEP, and their descriptions, starting from the top left:

- **Title Bar**: The Title Bar is the top-most bar shown in Figure 1. This bar contains the name of the program, software version number, system serial number (as SN:IHSXXXX), and hardware identification (as hardware type code and hardware serial number). The current modality of operation is shown to the right of the system information.
- **Main Menu**: The menu bar is located right under the Title Bar and allows access to almost all functions of the program. The items shown in the main menu will vary based on system configuration. Descriptions of all items in the main menu can be found in the Main Menu section of this manual.
- **Indicator Bar**: It is located below the Main Menu and contains some general information about the currently loaded patient file and selected waveform. From left to right, the indicator shows:
  - The patient identifier,
  - Recording name,
  - Peak-to-peak amplitude,
  - Signal-to-noise ratio,
  - Residual noise,
  - Mouse pointer amplitude position,
  - Mouse pointer time position, and
  - Current display page.
- **Tool Bar**: Below the indicator line, there is a toolbar that houses buttons equivalent to the most commonly used menu items. It contains buttons for patient files, peak markings, printing, data load and save, report load, and save, organizing recordings, and filtering. See the Main Screen section of this manual for a detailed description. The toolbar can be hidden by using the corresponding option in the **[Show]** menu.
- **Recording Area**: The large white area at the left and center of SmartEP. This area contains all recordings acquired or loaded. The time scale is shown at the bottom of this area. At the top left, a vertical scale marker shows the current microvolt scale, it can be set to a specific microvolt value or normalized for either individual waveforms or the entire page. The vertical scale marker may be moved by dragging it from the top handle. There are ten recording display areas available, one per report page and accessible from the side menu; only one of them can be viewed at a time.
- **Control Panel**: This collection of buttons contains the most frequently used acquisition controls and resides at the bottom of the screen; it is only present while on the acquisition page **[Acq]**. From here you can also access other controls such as the Auditory Stimulus Generation window, and various setup modules for the different, more specialized, modalities in SmartEP.
- **Side Menu**: It is located to the right of the recording area. It shows buttons corresponding to the acquisition page and the other 9 report pages. The report page numbers may be renamed using the options available in the **[Report]** menu. To the right of the page buttons, a scroll bar allows the user to move the view of the recording area to see the table. It also contains buttons for setting page display parameters and to show/hide the EEG panel and the recording information panel. At the bottom of the menu, the Amplifier Button opens the Amplifier Settings window, where the acquisition filters may be modified. When in Somatosensory mode, a current return indicator shows whether the electrical stimulation is currently active, and how much current return is being registered; a slider next to this indicator can be used to increase and decrease the intensity of the electrical stimulation.
- **Recording Information Panel**: It is the panel shown immediately to the left of the recording area in Figure 1. This panel can be shown/hidden when the **[Rec Info]** button is pressed on the side menu. It contains all pertinent information about the selected response organized in multiple tabs.
- **EEG Panel**: It is the panel shown to the right of the window in Figure 1. The live EEG can be seen on this panel when active. To activate the panel, click on the **[EEG]** button in the side menu. For the Duet platform, the area also shows a **[Check Impedance]** button and the results below the EEG; as well as a channel display option to show either of the two channels, or both simultaneously.

Keyboard shortcuts

The following keyboard shortcuts can be used to access certain functions in SmartEP.

- **[G]**: starts acquisition.
- **[Esc]** or **[Space]**: pause or stop a recording.
- **[A]** or **[0]**: Switches the display to the acquisition page.
- **[1]** through **[9]**: Switches the display to the correspondingly numbered page.
- **[P]**: Displays the Set Page menu.
- **[E]**: Opens the Amplifier window.
- **[N]**: Opens the Patient List window
- **[S]**: Cycles the selection through the recordings on the page.
- **[I]**: Arranges the recordings on the page by Intensity.
- **[O]**: Arranges the recordings on the page by order of acquisition time.
- **[R]**: Arranges the recordings on the page by stimulus repetition rate.
- **[F]**: Arranges the recordings on the page by stimulus type (or frequency of the stimulus)
- **[+]**: Adds all the currently selected recordings into a new average.
- **[-]**: Subtracts the two selected recordings and places the result into a new average.
- **[↑]** or **[↓]**: Moves the currently selected recording higher or lower on the page.
- **[Ctrl]** + **[↑]** or **[↓]**: Moves multi-selected waveforms higher or lower on the page
- **[←]**, **[<]**, **[→]** or **[>]**: Moves the selected label's latency marker on the time scale.
- **[Shift]** + **[←]** or **[Shift]** + **[→]**: moves the latency marker by a larger amount.
- **[Alt]** + **[←]** or **[Alt]** + **[→]**: moves the selected label's amplitude marker on the time scale.
- **[Shift]** + **[Alt]** + **[←]** or **[Shift]** + **[Alt]** + **[→]**: moves the amplitude marker by a larger amount.
- **[Ctrl]** + **[S]**: Selects all the recordings that were acquired simultaneously with the selected waveform
- **[Ctrl]** + **[C]**: Clears all data and objects on the current page

Default settings

The SmartEP software comes pre-loaded with a set of default ABR acquisition settings. These default values will be loaded every time the software opens. In cases where the system will be used most often for acquisition other than click ABR, you may wish to create a new default settings file to load at start-up. To do this:

1. Switch the modality using the options in the SmartEP main menu, under **[Protocol > Modality]**, if needed.
2. Accept the default parameters for the mode at first, and then change the acquisition parameters using the Control Panel buttons to fit the required values.
3. Click on the **[Stim]** button from the Control Panel to select your stimulus. Then click **[OK]** when done.
4. Click on the **[Amplifier]** button from the Side Panel and set your filters, gain, and artifact rejection settings. Remember to do this for all AEP channels that will be used. Click **[OK]** when done.
5. Click on the **[Save Settings]** button.

The software automatically assigns the name 'SEPWIN.SET' in the file name field. Since this is the name SmartEP uses for default parameters, leave it as is and click the **[Save]** button. Changing the name will result in saving a settings file that can be loaded manually; however, it will not automatically load on start-up.

Just in case someone overwrites the default settings file accidentally, it is recommended to make a backup of your default settings. To do this, simply click again on the **[Save Settings]** button and enter a name such as 'MyDefaultSEPSettings.SET' in the file name field, then click the **[Save]** button. If you ever need to re-save your defaults, load the backup file using the **[Load Settings]** button, then continue with the steps as shown above.

As with any other data stored on your computer, it is a good idea to keep backup copies of the settings files, especially if you do not keep printed records of the values used. The settings files can be found inside the "C:/IHSPROGS/Settings_EP" folder. When backing up settings files, it is also recommended to back up the stimulus files contained in "C:/IHSPROGS/Stim_EP".

Default normative data

Latency-Intensity normative data can be used to compare the results of one subject to the general population, comparing specific data to expected results. The SmartEP software has a built-in 'Lat-Int' data table that can be used for ABR responses. Default normative data needs to be activated manually, and it is recommended that normative data be established for the type of population you will be testing. Normative data is saved in two types of files:

- **Standard**: these files are used for saving normative data corresponding to different age groups, this data can be saved as SmartEP default, which will be shown automatically when opening the Lat-Int graph. The data also self-adjusts based on the age of the patient, as calculated based on the corresponding entries in the Patient Demographics window.
- **Special**: these files are used to save normative data corresponding to a specific population. These files can be loaded directly from the Lat-Int graph using the **[Norms]** button.

Loading default norms into SmartEP

1. From the LaunchPad main menu, click on **[Utilities > SmartEP Latency-Intensity Norms]**. Enter the system password to continue.
2. In the 'Latency-Intensity Table Generation' window, click on **[File > Load Norms]**.
3. Select a norms file from the list in the 'Open' file selection window, and then click the **[Open]** button.
4. Confirm that these are the values you intended to load, switch around the different age brackets on the right-hand side to view all the different values, as necessary.
5. To save the norms as default, click on **[File > Save Norms as SmartEP defaults]**.

If SmartEP was open during this operation, close and restart it. If you're currently working on a patient, save the data as a report before closing SmartEP to make it easier to reload after restarting.

Workflow

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The following are the expected workflows, on a day-to-day basis, when using SmartEP for evoked potential acquisition. The outlined steps, including specific menu items and buttons to use, are explained in detail in their corresponding chapters of this manual.

Single session workflow

1. Verify all hardware connections, making sure all the required equipment for the type of test is connected.
2. Check the device and accessories for cleanliness; refer to the hardware installation manual for more information about cleaning and maintenance, if necessary.
3. Turn ON the equipment and computer.
4. Create a new patient file in the Launch Pad program; see Creating a new patient file on page 18 for details. Or load an existing patient file; see Loading a patient file on page 18.
5. Open the SmartEP program.
6. Load a previously save settings file or change the software modality and testing parameters as needed. See Block Acquisition and Averaging on page 45 for details about modalities and their parameters.
7. If you will be using a previously saved Page Labels and Attributes file, load it now before starting acquisition. See Renaming Report Pages on page 76 for details.
8. Prepare the patient by placing electrodes and stimulators, as necessary. Alternatively, this step can be performed before entering the patient information, allowing for all conductive substances to sit in place reducing impedances. Refer to Patient Preparation on page 21 for instructions.
9. Start acquisition manually by clicking the **[Acquire]** button at the bottom left of the SmartEP window, or by executing an automated protocol. For Automating acquisition with protocols on page 52.
10. Modify levels and other parameters as needed and continue with acquisition until all the required data is acquired.
11. Once done, and satisfied with the acquired data, release the patient by removing electrodes and stimulators.
12. Finish arranging the recordings on the pages. See Moving recordings into report pages on page 74.
13. Label recordings with corresponding peak labels.
14. Save the data as a report to allow for easy retrieval in the future, then print pages if needed for your records, or save as a PDF document if keeping electronic records.
15. Use one of the “Transfer results to…” options from the main menu if using the IHS database or a supported external database.
16. Exit SmartEP, then perform database transfers as needed.
17. Turn OFF all devices and the computer if finished for the day.
18. Clean the devices and accessories as needed.
19. Store the device, accessories, and disposables in a clean secure area.

Multi-session workflow

In some instances, when time-constrained for time or due to other complications, it may be necessary to span a test over several sessions: for example, when performing a multi-frequency threshold search. To test over multiple sessions, follow the standard workflow for the first session, and then do the following for each of the sessions after that:

1. Follow steps 1 to 3 of the standard workflow. Verifying the hardware connections, equipment cleanliness, and turning the equipment ON.
2. Open the existing patient file either from the Launch Pad program or from SmartEP.

3. Open SmartEP if it is not already open.
4. Load the previously saved report (see step 14 of the standard workflow).
5. Follow steps 6 to 13 of the standard workflow. Checking the acquisition parameters, preparing the patient, acquiring the needed data, and organizing the newly acquired recordings.
6. Save the report with the same name as before to update it (or a different name if keeping track of changes), then print pages or save to PDF as needed.
7. Continue with the standard workflow from step 17 to the end. Turning off the devices, cleaning as needed, and placing them in the appropriate storage location.

Patient File Management

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Patient Files

When testing a new patient or test subject, a patient file should be created. The patient file holds the demographic information including name, identification numbers, date of birth, and other important details about the patient. Upon creation, a new folder is generated in the 'IHSData' folder; this patient folder will have the same name as the assigned patient identifier and will contain all data, reports, and digital documents for that patient. If the patient file was created, or loaded, from the Launch Pad application just before starting SmartEP, then the patient information will be loaded automatically, and you can proceed with testing immediately. Otherwise, create or load a patient file as follows. For additional information, refer to your hardware platform's reference documentation (see page 10).

Creating a new patient file

To create a new patient file:

1. From the main menu, click on **[Patient > New]**.
2. Enter a custom "**Identifier"** or keep the identifier that is automatically assigned. The automatic identifier includes the system serial number and a date code. Identification numbers such as hospital patient numbers can be used in this field. This field cannot be left blank, and it must be unique to that patient. This field is searchable from the patient list window.
3. Enter the "**First Name**" and "**Last Name**". Both fields are required. A small hand pointing button indicates that a required field is missing information. Both fields are searchable from the patient list.
4. Enter information on the additional fields located on the different tabs as needed. Note that none of those additional fields are required. However, the date of birth and gestation fields may be important if you are testing infants and toddlers, and you will be using Latency-Intensity Norms. The "**Main ID**" field is the only one of these that is searchable from the patient list window.
5. Click **[OK]** to finish.

You will notice that the patient file has been created by looking at the indicator bar. The patient identifier for the file that was just created can be found to the left, the full patient's name follows.

Loading a patient file

A patient file that has been previously created can be loaded to continue with data acquisition or to analyze the pre-acquired data. To load an existing patient file:

1. From the main menu, click on **[Patient > Open]**.
2. The Patient List window will show the list of all patient folders in the 'IHSData' folder. Note that to comply with privacy regulations, first names and last names are hidden; to view, check the **[Show First and Last Name]** box, refer to your hardware platform's reference documentation (see page 10) for instruction on how to modify this behavior.
3. Select the patient file you wish to load. The selected patient file will be highlighted in blue. Use the "**Search**" field if necessary to find any string in any of the four columns.
4. Click the **[OK]** button to load. The Patient Demographics window will open to confirm your selection.
5. Click **[OK]** again to fishing loading the Patient File.

If a specific patient is not found, it may be because the list is outdated. Click on the **[Refresh List]** button at the top right of the patient list window to update it with all the patient folders currently residing in the '**IHSData**' folder. If the patient still does not show after refreshing the list, it is possible that the patient was stored to another data directory, outside of the 'IHSData' folder (or the current folder being used for patient file storage.) You may try to locate the patient in another directory using the **[Change Dir]** button.

Editing patient information

Patient demographic information can be edited directly from SmartEP, the same way it is done from the Launch Pad program:

1. From the main menu, click on **[Patient > Edit]**. Notice the name of the current patient is listed on the menu item.
2. With the Patient Demographics window open, edit the information in the patient fields as needed. Do not change the "Patient Identifier", "First Name" initial, or "Last Name" initial (anything after the initials can be changed); these 3 fields are used for folder and file naming, changing any of these three items may cause previously recorded data to be inaccessible.
3. Click the **[OK]** button to confirm the changes.

Printing patient information

Once the patient is loaded, click on **[Patient > Edit]** from the main menu, then click on the **[Print]** button on the right-hand side of the Patient Demographics window. The information will be sent to the current default printer, make sure to set the printer you want as the Windows default before pressing the **[Print]** button.

Backing up a patient file

To back up a single patient file:

1. Open the Patient Demographics window with the patient file that needs to be backed up, then click on the **[Backup]** button on the right-hand side of the window. This will open the Backup and Restore Utility with the current patient selected.
2. Change the backup options at the bottom of the window as needed.
3. When ready, then press the **[Backup Selected Data]** button located at the bottom-eft of the window.

For additional information about the usage of the Data Backup and Restore Utility, and for instructions on backing up multiple patients, refer to your hardware platform's reference documentation (see page 10).

Restoring a patient file

To restore a single patient file from SmartEP:

1. Open the Patient Demographics window by clicking on **[Patient > New]** from the SmartEP main menu, or one of the patient buttons from the toolbar, then click the **[Backup]** button on the right-hand side of that window.
2. When the Data Backup and Restore Utility, click on the **[Select Source Drive]** button and choose the location of the patient file you want to restore.
3. Click on the **[Select Destination Directory]** button and choose the '**IHSData'** folder in your main drive.
4. Select the patient file from the list by clicking once on the row corresponding to that patient from the list. The cell under the '**Selected'** column should now read "Selected".
5. Make sure the '**Data'** and '**Summary'** boxes are checked, then press the **[Backup Selected Data]** button.

For additional details about the Data Backup and Restore Utility and instructions on how to restore multiple patients, refer to your hardware platform's reference documentation (see page 10).

Deleting a patient file

Caution:
Deleting patient files is an irreversible process. Deleted data cannot be recovered unless it has been previously backed up to another data storage location.

Deleting a patient file

1. With the patient file already loaded, from the LaunchPad program's main menu, click on **[Patient > Backup & Delete Data]**.
2. Click on the **[Delete]** button at the right-hand side of the Patient Demographics window.
3. Click **[OK]** to confirm.

Deleting multiple patient files

1. From the LaunchPad program's main menu, click on **[Patient > General Data Backup Utility]**.
2. Select patient files from the list by clicking on the corresponding row or using the selections tools at the top of the window. Selected patients will be indicated in the **Selected** column.
3. Click **[Delete Selected Data]**, then enter the system password to start the process.
4. Click **[Close]** when done.

Patient Preparation

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Patient Eligibility

Before acquiring evoked potentials from the patient, be aware of conditions that may impair your ability to acquire such potentials.

- Some medications, including antibiotics, may cause temporary or permanent toxicity that could affect the results of a hearing evaluation.
- Choose the best-suited stimulator; some medical conditions may prevent proper stimulator use, such as when the ear canal is compromised.
- Be aware of skin conditions that could prevent standard electrode use or produce adverse reactions to skin contact.

Patient State

- Instruct the patient on what to expect before starting, including levels of stimulation and any other sensations they may experience during acquisition.
- The patient must be in a relaxed state. To avoid post-auricular muscle artifacts, laying down is preferred to sitting. The only exception is P300 acquisition, where the patient must be alert and consciously discriminate between stimuli.
- The patient may be awake or asleep. Sleep is recommended. Infants are easier to test shortly after feeding. Sedation is not necessary for the acquisition of auditory evoked responses and should only be used by personnel properly trained in sedation techniques.
- The patient should avoid stimulants, or any drugs that may hinder normal nervous system behavior. If avoidance is not feasible, then the effect of these substances must be considered when evaluating the patient's responses.

Skin Preparation

When using surface electrodes, good impedance values will lead to less recording noise and more repeatable responses. Follow your institution's standard procedures for skin preparation, as they supersede any recommendations provided in this manual.

- Gently clean the skin with an alcohol pad to remove excess oil or makeup at the intended electrode placement locations.
- If necessary, mildly rub the electrode locations with a soft cloth pad such as gauze and some approved impedance reducing abrasive gel. Consider specific patient needs for skin sensitivity and follow the gel manufacturer's instructions. Skip this step when the patient is a newborn, small infant, or for patients with extremely sensitive skin.
- Check the expiration date of disposable electrodes. Expired electrodes may result in noisy recordings, bad impedances, or detaching electrodes.
- A small amount of conductive gel may be added to the electrode sensor area of disposable electrodes before placement to improve impedance. Using too much gel may prevent the electrode from sticking. Let the electrodes sit in place for a few minutes before acquisition to improve impedances.
- Do not press disposable electrodes onto the skin by the sensor area; press the sides of the electrode instead. Pressing the sensor area may force any conductive gel into the adhesive area, causing the electrode to fail to adhere, or to detach later mid-test.
- When using reusable electrodes such as gold cup electrodes, make sure to use enough conductive paste and then secure them in place by using a small piece of surgical tape. A piece of gauze between the electrode and the surgical tape can be added for electrode stability.

Electrode polarity and activation

It is important to keep in mind the polarity of the electrodes when acquiring evoked responses. Reversing the polarity will cause the waveforms to be inverted. Each platform treats the electrode lead sockets a different way. The following subsections can be used as a guide to verify electrode socket polarity based on the selected test settings and operating mode.

Warning:
When using single-channel modes, make sure to choose the correct option in the menu. Only use 3-snap lead patient cables or 3 electrode lead patient cable for 'Single Mode with 3 Lead Cable'. Only use the 5 electrode leads patient cable for 'Single Mode with 5 Lead Cable'. The 4-snap leads electrode cable should never be used while the Duet is set to either of the single channel modes, doing so may lead to inaccurate results.

Duet: dual channel mode connection setup

When using the 4-snap leads patient cable or the 5-electrode leads patient cable on a Duet, the polarities are as follows:

- The Red and Blue electrodes are the inverting electrode (-) for the right channel and left channel, respectively.
- The Black electrode is the ground electrode.
- The White and Grey electrodes are the non-inverting electrode (+) for the right channel and left channel, respectively. In the 4-snap leads patient cable, the electrode is a joint (right and left) non-inverting electrode.

	Red	White	Black	Grey	Blue
4-Snap Leads Patient Cable	Right (-)	Joint (+)	Ground	---	Left (-)
5 Electrode Leads Patient Cable	Right (-)	Right (+)	Ground	Left (+)	Left (-)

Table 1

Duet: single channel connection setup

The Duet may be set to a special single-channel acquisition modes, only when using the Auditory modality options. There are two modes available, one for use with 3-electrode lead patient cable and the 3-snap lead patient cable: a second mode for use with the 5-electrode lead patient cable. In these modes, the electrode polarities are changed automatically based on the settings chosen in the software. Note that the Red and Blue/Black electrodes switch polarities automatically when the settings are modified in the SmartEP software, while the White electrode will always remain constant (as the non-inverting electrode.) The main governing settings controlling electrode polarity are:

- **Amplifier Designation**: This setting can be found inside the Amplifier settings window. The options are 'Left-Right' and 'Midline'. In Midline mode, the electrodes work the same way they do when using the Solo with the SmartScreener-Plus software. In Left-Right mode, a horizontal array electrode placement is expected.
- **Mode**: This is a button on the control panel. The settings are Ipsilateral (Ipsi) and Contralateral (Contra), switching the red and blue electrode polarity. Notice that if the stimulus ear is set to both, the electrodes maintain the same polarity whether the mode is set to Ipsi or Contra.
- **Ear**: This is the button found in the control panel. The settings are 'Left', 'Right', and 'Both'; switching the sound output based on the selection made. When the designation is set to 'Left-Right', switching the ear will also change the electrode polarity.

In the following tables, a (+) sign represents the position of the non-inverting electrode, while a (-) sign represents the position of the inverting electrode.

When using the 3-snap lead patient cable or the 3-electrode lead patient cable, the polarities are as follows:

EEG Designation	Right-Left						Midline
Recording Mode	Ipsilateral			Contralateral			Any
Stimulation Ear	Right	Left	Both	Right	Left	Both	Any
Red Socket	Ground	Inv (-)	Ground	Inv (-)	Ground	Ground	(-)
White Socket	Non-Inv (+)			Non-Inv (+)			(+)
Blue Socket	Inv (-)	Ground	Inv (-)	Ground	Inv (-)	Inv (-)	Ground

Table 2

When using the 5-electrode lead patient cable, the polarities are as follows:

EEG Designation	Right-Left						Midline
Recording Mode	Ipsilateral			Contralateral			Any
Stimulation Ear	Right	Left	Both	Right	Left	Both	Any
Red Socket	Ground	Inv (-)	Ground	Inv (-)	Ground	Ground	(-)
White Socket	Non-Inv (+)			Non-Inv (+)			(+)
Black Socket	Inv (-)	Ground	Inv (-)	Ground	Inv (-)	Inv (-)	Ground

Table 3

USB Box and USB Jr.: single-channel transmitter

The single-channel transmitter box has three electrode positions: Red, Blue, and Black. The functions of each position need to be physically switched on the Opti-Amp transmitter by flipping the 'Left-Right' lever to the correct position. Failing to change the lever position may result in an inverted recording; however, the response will be acquired regardless of settings. The Amplifier designation setting only has ON and OFF positions, setting the channel to OFF will prevent acquisition regardless of any other settings.

When the Switch is set to Right on the Amplifier:

- The Red electrode is the inverting electrode (-).
- The Blue electrode is the ground.
- The Black electrode is the non-inverting electrode (+).

When the Switch is set to Left on the Amplifier:

- The Red electrode is the ground.
- The Blue electrode is the inverting electrode (-).
- The Black electrode is the non-inverting electrode (+).

	Red	Black	Blue
Switch set to Right	Inv (-)	Non-Inv (+)	Ground
Switch set to Left	Ground	Non-Inv (+)	Inv (-)

Table 4

USB Box and USB Jr.: dual-channel transmitter

The dual-channel transmitter box has five electrode positions: two Red, two Blue, and one Black. In this type of transmitters, the Red positions are always the inverting electrodes (-), the Blue positions are always the non-inverting electrodes (+), and the Black position is always the ground. The polarity of the electrode positions will not change regardless of software settings. Channel designation can be changed in the Amplifier window independent of channel label (A, B, C, etc.…); each channel can be defined as Right, Left, ON, or OFF. The software will decide which channel to acquire from based on this designation and the parameters specified for ear and mode in the control panel.

Recording Mode	**Ipsilateral**			**Contralateral**			**Both**
Stimulation Ear	**Right**	**Left**	**Both**	**Right**	**Left**	**Both**	**Any**
Designation: Right	Yes	-	Yes	-	Yes	Yes	Yes
Designation: Left	-	Yes	Yes	Yes	-	Yes	Yes
Designation: ON	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Designation: OFF	-	-	-	-	-	-	-

Table 5

Normally Channel A is designated to be the Right channel, while Channel B is designated to be the Left channel. As an example, if you set the recording mode to 'Ipsilateral', and the stimulation ear to be 'Right'; then as shown on the table, only channels designated as 'Right' or 'ON' will acquire. Then in this example, only Channel A will acquire while Channel B will not.

USB Box: large, multichannel transmitter

Systems with more than two acquisition channels use a large Opti-Amp transmitter box, which can house up to eight pre-amplifier channels. The unit will have a variable amount of Red and Blue electrode sockets, based on the number of channels. All Red sockets correspond to inverting electrodes (-), and all Blue sockets correspond to non-inverting electrodes (+) for their respective channels. The Black electrode socket is always the ground electrode.

Channel designation can be changed in the Amplifier window; each channel can be defined as Right, Left, ON, or OFF. The software will decide which channel to acquire from based on this designation, and the parameters specified for ear and mode in the control panel (see Table 5). Channels that will not be used should be assigned the designation OFF and should be physically shorted using a Y-adapter. Channels that should always acquire should be assigned the designation ON, that way they will acquire regardless of Ear or Mode settings. Note that multiple channels can be designated to the same side; E.g. having channels A, B and C designated to Right will make all three of them acquire when the ear is set to right and the mode is set to ipsilateral, while they will not acquire when the ear is set to left and the mode is set to ipsilateral.

Solo connection setup

The Solo hardware unit contains a built-in single-channel differential amplifier. Regardless of the electrode type, the unit has a Red, Blue, and White electrode lead (or sockets). These colors are mapped internally by the hardware to the inverting (-), non-inverting (+), and ground connectors on the amplifier as outlined in the following table. Note that the Red and Blue electrodes switch polarities automatically when the settings are modified in the SmartEP software, while the White electrode will always remain constant (as the non-inverting electrode.) The main governing settings controlling electrode polarity are:

- **Amplifier Designation**: This setting can be found inside the Amplifier settings window. The options are 'Left-Right' and 'Midline'. In Midline mode, the electrodes work the same way they do when using the Solo with the SmartScreener-Plus software. In Left-Right mode, a horizontal array electrode placement is expected.

- **Mode**: This is a button on the control panel. The settings are Ipsilateral (Ipsi) and Contralateral (Contra), switching the red and blue electrode polarity. Notice that if the stimulus ear is set to both, the electrodes will keep the same polarity whether the mode is set to Ipsi or Contra.
- **Ear**: This is the button found in the control panel. The settings are 'Left', 'Right', and 'Both'; switching the sound output based on the selection made. When the designation is set to 'Left-Right', switching the ear will also change the electrode polarity.

In the following table, a (+) sign represents the position of the non-inverting electrode, while a (-) sign represents the position of the inverting electrode.

EEG Designation	**Right-Left**						**Midline**
Recording Mode	**Ipsilateral**			**Contralateral**			**Any**
Stimulation Ear	**Right**	**Left**	**Both**	**Right**	**Left**	**Both**	**Any**
Red Socket	Ground	Inv (-)	Ground	Inv (-)	Ground	Ground	(-)
White Socket	Non-Inv (+)			Non-Inv (+)			(+)
Blue Socket	Inv (-)	Ground	Inv (-)	Ground	Inv (-)	Inv (-)	Ground

Table 6

USBLite connection setup

The USBLite hardware unit contains a built-in single-channel differential amplifier. Regardless of the electrode type, the unit has a Red, Blue, and Black electrode lead (or sockets). These colors are mapped internally by the hardware to the inverting (-), non-inverting (+), and ground connectors on the amplifier as outlined in the following table. Note that the Red and Blue electrodes switch polarities automatically when the settings are modified in the SmartEP software, while the Black electrode will always remain constant (as the non-inverting electrode.) The main governing settings controlling electrode polarity are:

- **Amplifier Designation**: This setting can be found inside the Amplifier settings window. The options are 'Left-Right' and 'Midline'. In Midline mode, the electrodes work the same way they do when using the USBLite with the SmartScreener-Plus software. In Left-Right mode, a horizontal array electrode placement is expected.
- **Mode**: This is a button on the control panel. The settings are Ipsilateral (Ipsi) and Contralateral (Contra); switching the red and blue electrode polarity. Notice that if the stimulus ear is set to both, the electrodes will behave the same regardless of mode.
- **Ear**: This is the button found in the control panel. The settings are 'Left', 'Right', and 'Both'; switching the sound output based on the selection made. When the designation is set to 'Left-Right', switching the ear will also change the electrode polarity.

In the following table, a (+) sign represents the position of the non-inverting electrode, while a (-) sign represents the position of the inverting electrode.

EEG Designation	**Right-Left**						**Midline**
Recording Mode	**Ipsilateral**			**Contralateral**			**Any**
Stimulation Ear	**Right**	**Left**	**Both**	**Right**	**Left**	**Both**	**Any**
Red Socket	Ground	Inv (-)	Ground	Inv (-)	Ground	Ground	(-)
Black Socket	Non-Inv (+)			Non-Inv (+)			(+)
Blue Socket	Inv (-)	Ground	Inv (-)	Ground	Inv (-)	Inv (-)	Ground

Table 7

AEP Electrode Placement

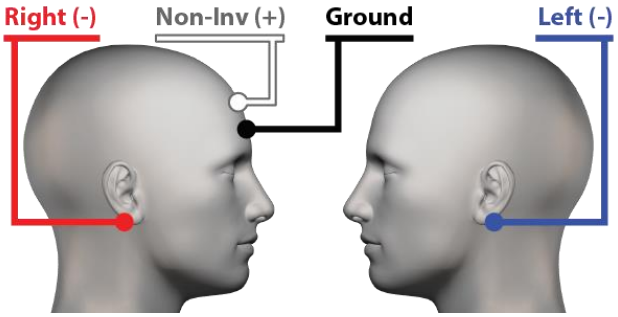
The following may be used as general guidance for electrode placement by hardware platform. Different acquisition protocols may call for electrode positioning that is different than the ones shown in this manual. 10-20 system electrode positions may be provided in parenthesis.

USB Jr. Duet: dual channel mode

The standard mode of operation for the USB Jr. Duet is Dual Channel. This is the mode that should be used when using the 4 Snap Leads Patient Cable or the 5 Electrode Leads Patient Cable. See **[Protocol > Duet Mode]** for current mode of operation, or to change modes.

Ipsi-Contra Array

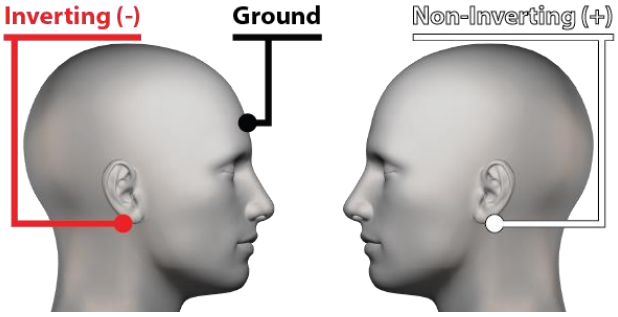
When using the 4 Snap Leads Patient Cable or the 5 Electrode Leads Patient Cable



- Right mastoid (A2) electrode, connected to the Red Inverting (-) electrode lead or socket.
- Left mastoid (A1) electrode, connected to the Blue Inverting (-) electrode lead or socket.
- High forehead (Fpz), or vertex, electrode connected to the White Non-Inverting (+) electrode lead or socket. If using the 5 Electrode Leads Patient Cable, join the White and Grey sockets using a Y-Adapter.
- Low forehead (Below Fpz) electrode, connected to the Black ground electrode lead or socket.

Single Channel Horizontal Array – Right Ear

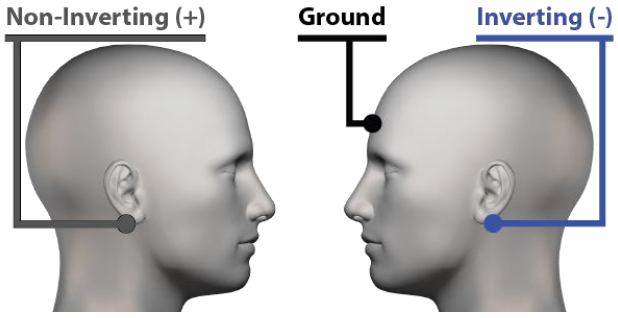
When using the 5 Electrode Leads Patient Cable



- Right mastoid (A2) electrode, connected to the Red Inverting (-) electrode socket.
- Left mastoid (A1) electrode, connected to the White non-inverting (+) electrode socket.
- Forehead (Fpz) electrode, connected to the Black ground electrode socket.
- The Blue and Grey sockets must be joined via Y-Adapter plugs. The Y-Adapter socket is left disconnected.

Single Channel Horizontal Array – Left Ear

When using the 5 Electrode Leads Patient Cable



- Left mastoid (A1) electrode, connected to the Blue Inverting (-) electrode socket.
- Right mastoid (A2) electrode, connected to the Grey non-inverting (+) electrode socket.
- Forehead (Fpz) electrode, connected to the Black ground electrode socket.
- The Red and White sockets must be joined via Y-Adapter plugs. The Y-Adapter socket is left disconnected.

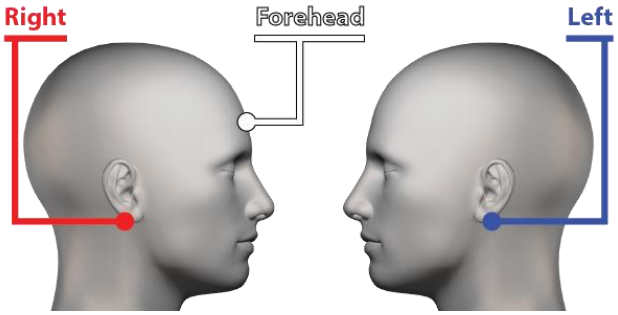
USB Jr. Duet: Single Channel Mode

This is the mode that should be used when using the 3 Snap Leads Patient Cable or the 3 Electrode Leads Patient Cable. In Single Channel mode, the designation must be set inside the Amplifier window. See **[Protocol > Duet Mode]** for current mode of operation, or to change modes.

Right-Left Designation

When using the 3 Snap Leads Patient Cable or the 3 Electrode Leads Patient Cable . For this designation, the non-inverting electrode will switch between Red (right) and Blue (left) based on the ear selection.

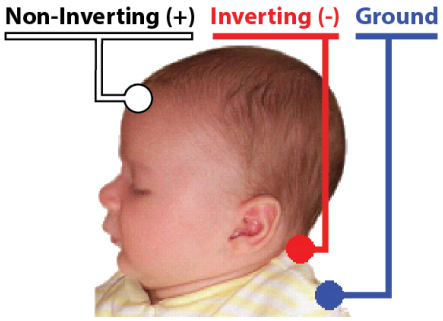
- Right mastoid (A2) electrode, connected to the Red electrode lead or socket.
- Left mastoid (A1) electrode, connected to the Blue electrode lead or socket.
- Forehead (Fpz), or vertex, electrode connected to the White non-inverting (+) electrode lead or socket. .



Midline Designation

When using the 3 Snap Leads Patient Cable or the 3 Electrode Leads Patient Cable In this mode, the polarity of the electrodes stays constant.

- Nape electrode, connected to the Red Inverting (-) electrode socket.
- Shoulder electrode, connected to the Blue ground electrode socket.
- Forehead (Fpz) electrode, connected to the White non-inverting electrode socket.



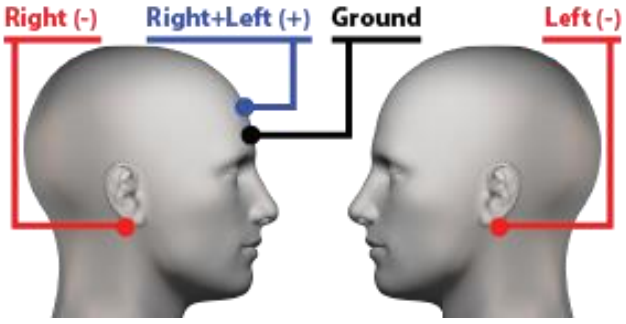
USB Box and USB Jr.

These setups are used with the USB Box and USB Jr. hardware platforms.

Dual-channel and multi-channel transmitter

This is the most commonly used setup for systems with two or more channels. This is the preferred setup since it allows easy switching between sides.

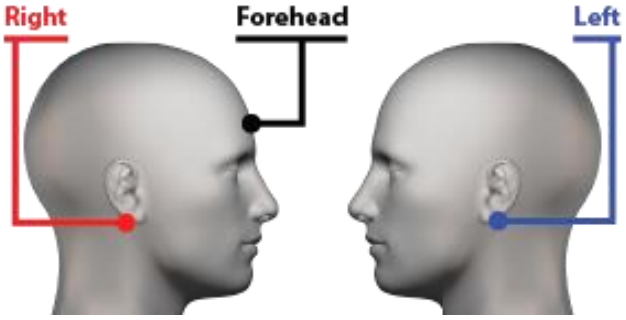
- Electrode on the right mastoid (A2), connected to the Right Red Inverting (-) electrode socket.
- Electrode on the left mastoid (A1), connected to the Left Red Inverting (-) electrode socket.
- Electrode on the high forehead (Fpz), or vertex, connected jointly to the Blue Non-Inverting (+) electrode sockets using a Y-adapter.
- Electrode on the low forehead (Below Fpz), connected to the Black ground electrode socket.



Alternatively, the mastoid electrodes can be positioned on the corresponding ear lobes to avoid PAM artifacts. Any unused channels should have their inverting and non-inverting sockets shorted using a Y-Adapter; the merged end of the Y-Adapter is left disconnected.

Using a Single Channel

This setup will generally be used when operating a single-channel unit, or when using just one of the channels in a multi-channel unit.



- Electrode on the right mastoid (A2), connected to the Right Red electrode socket.
- Electrode on the left mastoid (A1), connected to the Left Blue electrode socket.
- Electrode on the forehead (Fpz), connected to the Black non-inverting electrode socket.

Alternatively, the mastoid electrodes can be positioned on the corresponding ear lobes to avoid PAM artifacts. When testing both ears or when switching from ipsilateral to contralateral on the same ear:

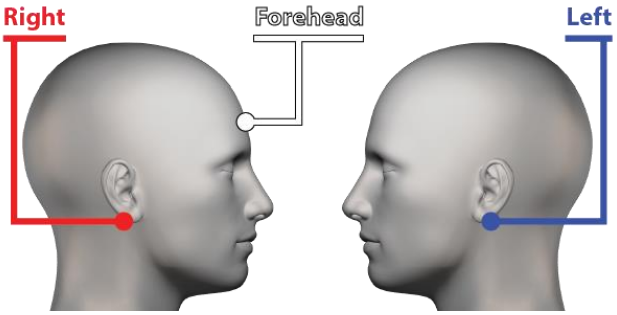
- **Single-channel transmitters**: flip the side switch on the transmitter between Left and Right to reverse polarity.
- **Multi-channel transmitters**: switch the cables connected to the Red and the Blue electrode positions to the appropriate channel, if using the same channel, simply swap them in the same channel. Any unused channels should have their inverting and non-inverting sockets shorted using a Y-Adapter; the merged end of the Y-Adapter is left disconnected.

Solo single-channel setup

These setups are recommended for use with the Solo hardware platform.

Right-Left Designation

This setup needs to be used when operating a Solo hardware unit, while the designation is set to Right-Left. If using this setup, make sure to select the 'Right-Left' electrode designation in the "Amplifier Settings" window.

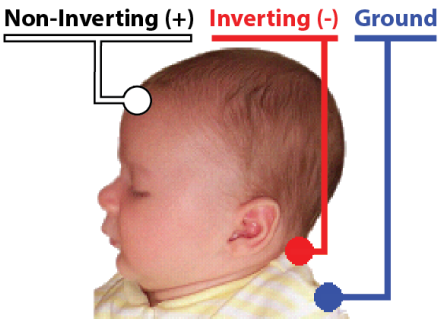


- Electrode on the right mastoid (A2), connected to the Right Red electrode lead or socket.
- Electrode on the left mastoid (A1), connected to the Left Blue electrode lead or socket.
- Electrode on the forehead (Fpz), connected to the White non-inverting electrode lead or socket.

Alternatively, the mastoid electrodes can be positioned on the corresponding ear lobes to avoid PAM artifact. When testing both ears or when switching from ipsilateral to contralateral, simply choose the appropriate option in the SmartEP control panel, the electrode polarity will change internally.

Midline electrode array for the Solo

This setup should be used when operating a Solo , while the designation is set to Midline. It can also be used when stimulating only one side at a time in SmartEP, or dual ears on SmartScreener-Plus or SmartEP-ASSR. If using this setup, make sure to select the 'Midline' electrode designation in the "Amplifier Settings" window.



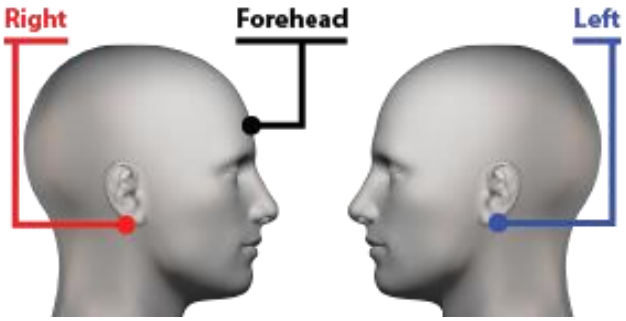
- Electrode on the Nape, connected to the Red Inverting (-) electrode position.
- Electrode on the Shoulder, connected to the Blue ground electrode position.
- Electrode on the forehead (Fpz), connected to the White non-inverting (+) electrode position.

USBLite single channel setup

These setups are used with the USBLite hardware platform.

Right-Left Designation

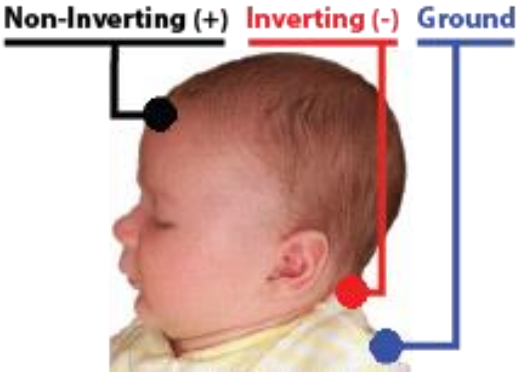
This setup needs to be used, when operating a USBLite hardware unit, while the designation is set to Right-Left. If using this setup, make sure to select the 'Right-Left' electrode designation in the "Amplifier Settings" window.



- Electrode on the right mastoid (A2), connected to the Right Red electrode lead.
- Electrode on the left mastoid (A1), connected to the Left Blue electrode lead.
- Electrode on the forehead (Fpz), connected to the Black non-inverting electrode lead.

Midline designation

This setup needs to be used when operating a USBLite hardware unit, while the designation is set to Midline. It can also be used when stimulating only one side at a time in SmartEP, or dual ears on SmartScreener-Plus or SmartEP-ASSR. This is the preferred setup for infant hearing screening. If using this setup, make sure to select the 'Midline' electrode designation in the "Amplifier Settings" window.



- Electrode on the Nape, connected to the Red Inverting (-) electrode lead.
- Electrode on the Shoulder, connected to the Blue ground electrode lead.
- Electrode on the forehead (Fpz), connected to the Black non-inverting (+) electrode lead.

ECochG electrode placement

Due to the nature of the ECochG responses, the electrodes need to be placed closer to the generator sites. The distance to the generator site will dictate the strength and morphology of the response.

Tip-Trodes

Tip-Trodes are the least invasive, and least uncomfortable, method to acquire ECochG responses. Electrode contact is achieved at the ear canal. Due to positioning, it may be a little more difficult to acquire a consistent response than with other methods. Single-channel or Dual-channel configurations can be used for acquisition. When using Tip-Trodes:

- Place the Tip-Trode on the special cable, making sure the alligator clip makes contact with the gold foil surface of the Tip-Trode.
- Make sure the ear canal is clean of debris; a clean ear canal will decrease impedance and result in better recordings. Only trained personnel should clean the ear canal.
- Roll the foam area between your fingers to decrease the diameter of the Tip-Trode before insertion.
- Use conductive paste on the Tip-Trode before placing it on the ear canal to decrease impedance.
- Pulling on the ear lobe down and toward the back of the head may help with Tip-Trode insertion, by aligning the ear canal slightly.
- Let the Tip-Trode fully expand before starting to record.
- Follow any other instructions on the Tip-Trode packaging.

TM-Wick electrodes

This type of electrode provides better responses since they are placed much closer to the generator site. Although they are not invasive, they can be uncomfortable. When using TM-Wick Electrodes:

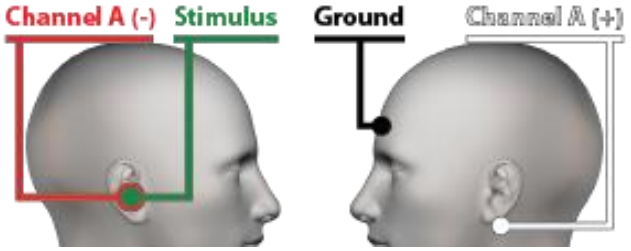
- Follow the instructions on the electrode package to rehydrate the electrodes.
- Make sure the ear canal and ear drum are clean of debris, a clean ear canal will decrease impedance and result in better recordings. Only trained personnel should clean the ear canal.
- Wick electrodes are more easily inserted when the patient is lying sideways, and the ear canal is vertical.
- Hold the TM-Wick electrode in place, then place the sound transducer foam tip and let it expand. Secure the electrode lead in place with surgical tape if necessary.
- Follow any other instructions on the TM-Wick electrode packaging.

USB Jr. Duet

Dual-channel mode is recommended when acquiring ECochG responses; if using single-channel mode, check Table 2 and Table 3 on page 23, as appropriate, to confirm electrode polarities. The following setups are for use with the Duet platform, while using dual-channel mode.

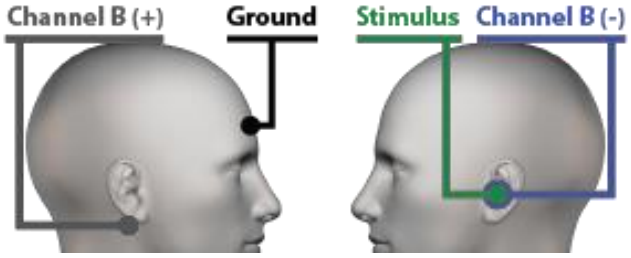
Horizontal array – Right ear

This is the preferred setup; the 5 Electrode Leads Patient Cable is required for ECochG acquisition.



- TM-Wick electrode or Tip-Trode inserted into the right ear, connected to the Red electrode position.
- Electrode to left ear mastoid or earlobe using a surface electrode, connected to the White electrode position. It may also be placed on the ear canal using a second Tip-Trode or TM-Wick electrode.
- Electrode to the forehead (below Fpz), connected to the Black electrode position.
- Blue and Grey electrode positions should be connected to each other using a Y-Adapter to short-out the channel; merged end is left unconnected.

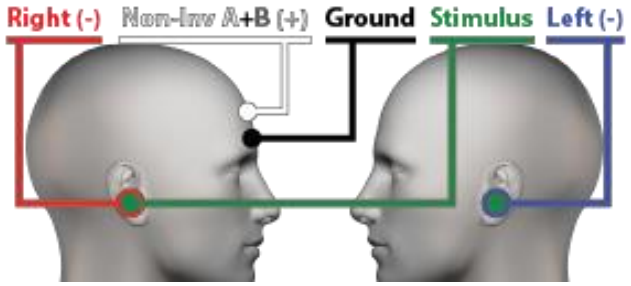
Horizontal array – Left ear

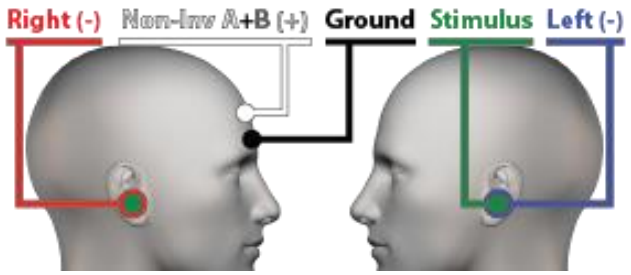


- TM-Wick electrode or Tip-Trode inserted into the left ear, connected to the Blue electrode position.
- Electrode to right ear mastoid or earlobe using a surface electrode, connected to the Grey electrode position. It may also be placed on the ear canal using a second Tip-Trode or TM-Wick electrode.
- Electrode to the forehead (below Fpz), connected to the Black electrode position.
- Red and White electrode positions should be connected to each other using a Y-Adapter to short-out the channel; merged end can remain unconnected.

Ipsilateral array

This is an alternate setup, useful when performing tests for both sides, or performing both ECochG and ABR, in a single session. The 5 Electrode Leads Patient Cable is required for ECochG acquisition.



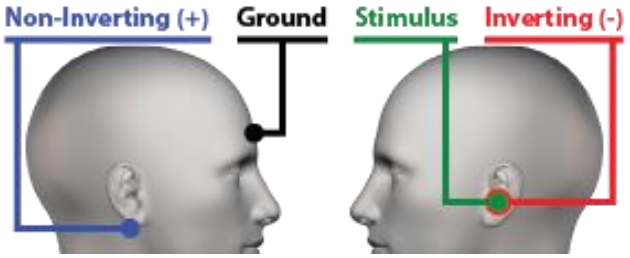


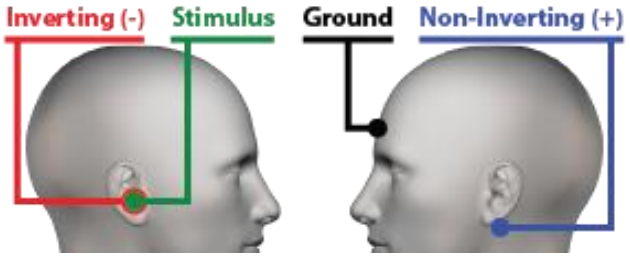
- TM-Wick electrode or Tip-Trode inserted into the right ear, connected to the Red electrode position.
- TM-Wick electrode or Tip-Trode inserted into the left ear, connected to the Blue electrode position.
- The White and Grey electrode positions should be connected to each other using a Y-Adapter; then connected to a surface electrode to the high forehead (Fpz).
- Surface electrode to the low forehead (below Fpz), connected to the Black electrode position.

ECochG electrode placement for USB Box and USB Jr.

Horizontal Array

This is the preferred setup when using multi-channel transmitters. It will result in a positive SP/AP. Reverse the polarities for a negative SP/AP.

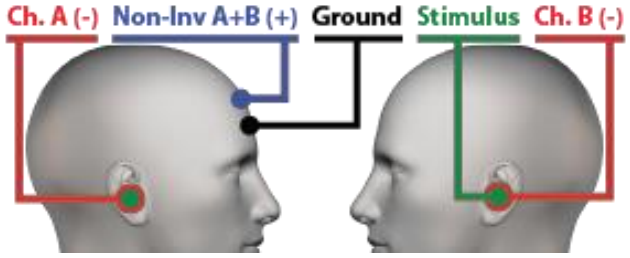


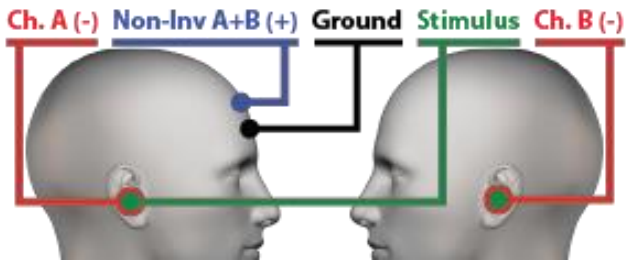


- TM-Wick or Tip-Trode inserted into the ipsilateral ear and connected to the Red inverting electrode position.
- Electrode to contralateral ear mastoid or earlobe using a surface electrode, connected to the Blue non-inverting electrode position. It may also be placed on the ear canal using a second Tip-Trode or TM-Wick electrode.
- Electrode to the forehead (below Fpz), connected to the Black ground electrode position.
- All other available channels should have their inverting (red) and non-inverting (blue) electrode positions connected to each other using a Y-Adapter to short-out the channels; merged end is left unconnected.

Multi-Channel Transmitter Ipsilateral array

This is an alternate setup when using a multi-channel transmitter; useful when performing tests for both sides, or performing both ECochG and ABR, in a single session.





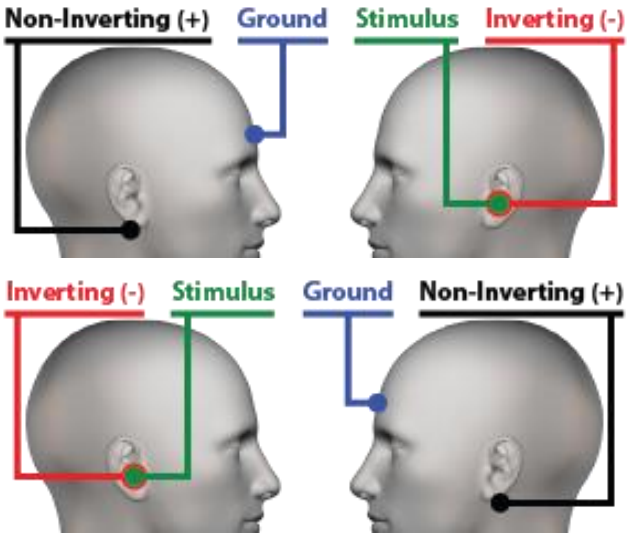
- TM-Wick or Tip-Trode inserted into the right ear, connected to the Channel A, Red electrode position.
- TM-Wick or Tip-Trode inserted into the left ear, connected to the Channel B, Red electrode position.
- Both Channel A and B Blue electrode positions should be connected jointly using a Y-Adapter to a surface electrode to the high forehead (Fpz).
- Surface electrode to the low forehead (below Fpz), connected to the Black electrode position.
- Any other available channels should have their inverting and non-inverting electrode positions connected to each other using a Y-Adapter to short-out the channels; merged end is left unconnected.

Single-channel transmitters

This setup is used when operating a single-channel unit.

- TM-Wick or Tip-Trode inserted into the ipsilateral ear canal and connected to the Red electrode position.
- Electrode on the contralateral mastoid (A1) or ear lobe, connected to the Black electrode position. It may also be placed on the ear canal using a second Tip-Trode or TM-Wick electrode.
- Electrode on the forehead (Fpz), connected to the Blue electrode position.

To change sides, flip the switch to the acquisition side and ensure the polarities match what is shown on the figures to the right, as applicable. If the polarity of the resulting is inverted, you may invert the waveform using the options in the process menu.



ECochG electrode placement for USBLite and Solo

Although acquisition of ECochG may be attempted using these platforms by referencing the polarities used for other hardware units, neither of these hardware units may be used effectively due to their internal hardware filters.

Checking electrode impedance

The different hardware platforms have their own procedure for checking impedances. All impedances are measured in Ohms. To obtain significant, clean, and repeatable responses it is better to have impedances close to 1 kΩ. Since the hardware is based on differential amplifiers, it is also better to have impedances that match across each channel; that is to say, it is better to have both the non-inverting and inverting electrodes with an impedance of 3 kΩ than having one at 5 kΩ while the other is at 1 kΩ.

For the Duet, Solo, and USBLite

The impedances for the Duet, Solo, and USBLite units are checked directly from the software:

1. Click on the **[Amplifier]** button from the SmartEP control panel, or the **[Show/Hide EEG]** button from the side menu until the EEG is shown.
2. Locate and click on the **[Check Impedance]** button.
3. When using the Amplifier window, an Impedance window will open, showing the values for each electrode position; when using the Amplifier graph on the side panel, the impedance values will show right below the button.

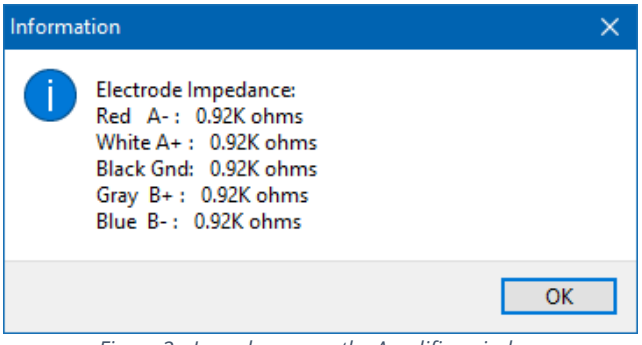


Figure 2 - Impedances on the Amplifier window.

For the USB Box and USB Jr.

Single Channel Transmitter

The impedances for the single-channel transmitter can be checked from the device by moving the rotary switch to the correct position. There are two impedance checking positions on the switch. As you check impedances, observe the colored LEDs for impedance values, green values are good, yellow are marginal, and orange are to be avoided. After checking impedances and before starting acquisition, make sure to set the rotary switch to the ON position.

Figure 3 - Front panel of the single-channel transmitter

Dual-channel transmitter for the USB Box and USB Jr.

The impedances for the Dual-channel transmitter can be checked from the device, by moving the rotary switch to the different positions. There are four positions, two per channel. As you check impedances, observe the colored LEDs for impedance values, green values are good, yellow are marginal, and orange are to be avoided. After checking impedances and before starting acquisition, make sure to set the rotary switch to the ON position. If a single impedance value is registering high, check the corresponding electrode. If impedance values are high for all electrodes, the black ground electrode is the one affected.

Figure 4 - Front panel of the Dual-channel transmitter

Large transmitter for the USB Box

The large transmitter has an array of impedance checking buttons at the front of the device, two per channel, corresponding to the Red and Blue sockets. All impedances are checked against the Black ground electrode socket. The switch for this unit needs to be on the ON position before testing impedances and must remain in the ON position for acquisition. As you check impedances, observe the colored LEDs for impedance values, green values are good, yellow are marginal, and orange are to be avoided. If a single impedance value is registering high, check the corresponding electrode. If impedance values are high for all electrodes, the black ground electrode is the one affected.

Figure 5 - Front panel of the large transmitter

Sound coupler placement

Proper sound coupler placement is essential for obtaining repeatable and reliable responses. Make sure to always use an adequate ear tip or similar to achieve a good seal. Also remember to set the software to the type of transducers being used, accurate calibration values depend on the selection of the correct transducer.

Insert earphones

The ER-3C, ER-3A, and ER2 Insert Earphones must be used in combination with a coupler. Consult your platform's documentation for part numbers.

- **EarHugs**: These adapters consist of a large hydrogel surface that adheres over the ear, providing sound to the ear without ear canal insertion. They require the use of special domino adapters at the end of the plastic tube that attaches to the earphone. They are meant to be used when testing premature and newborn babies, although they may be useful in other special situations. This option (ER3 Insert with EarHug) must be chosen explicitly from the Auditory Stimulus Generation window as it requires special calibration values.

- **Pediatric Foam Tips**: These are foam cylinders with a small sound tube in the center. They can be attached to the insert earphone tubing with a nipple. These are to be rolled between the fingers to reduce their volume before inserting them into the ear canal. Pulling slightly down and back on the earlobe may help straighten the ear canal and make placement easier. Hold in place, inside ear canal until the foam has fully expanded and created a seal. These are meant to be used with small children or adults with small ear canals.

- **Adult Foam Tips**: These are foam cylinders with a small sound tube in the center. They can be attached to the insert earphone tubing with a nipple. These are meant to be rolled between the fingers to reduce their volume before inserting them into the ear canal. Pulling slightly down and back on the earlobe may help straighten the ear canal and make placement easier. Hold in place, inside the ear canal until the foam has fully expanded and created a seal. These are meant to be used with adults or any other subject where the smaller tips fail to stay in place or provide a proper seal.

Headphones

Headphones should be used for patients when insert earphones are not suitable. They are especially helpful with patients with malformed ear canals, or certain types of hyper-sensitivity. Two transducers with cushioned circumaural pads placed over each ear are held by a headband. Use in a quiet environment is recommended as these transducers offer far less noise isolation than insert earphones. Keep the headphone cable from crossing electrode leads; crossing cables may increase artifacts and recording noise.

Bone conductor

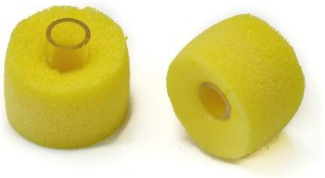
Bone conductors consist of a small vibrating device fastened to the head of the patient with a headband. The bone vibrator should be placed over easily accessible bone structure such as the mastoid, or forehead. Make sure the vibrator does not touch the electrodes; if placing the vibrator on a mastoid, you may want to place the electrode on the ear lobe. As with any other cables, keep the bone conductor cable from crossing electrode leads; crossing cables may increase artifacts and recording noise. Generally, when using the bone conductor, a masking stimulus should be provided to the contralateral (opposite) ear using the insert earphones.

OAE probe

The OAE probe primary use is for the acquisition of Otoacoustic Emissions, however it can also be used to provide stimulation for the acquisition of Auditory Evoked Potentials. It can be especially helpful when evaluating sleeping infants, removing the need to change stimulators when switching between AEP and OAE. Always use a properly fitting foam or plastic ear tip when using this probe to ensure a good seal. Keep in mind that the OAE probe has a reduced intensity range, other stimulators must be used for higher intensities.

- **Plastic Ear Tips**: These plastic tips come in different sizes; usually the sizes are different colors. Choose an appropriate size for the ear canal of the patient. Insert the tip over the OAE Probe cover tip, conical part of the probe, and push almost all the way in. It is recommended to leave a small gap, about one millimeter, between the end of the probe cover tip and the end of the ear tip, creating a small cavity; this helps minimize cerumen or vernix in the probe cover tip.

- **Foam Ear Tips**: These are foam cylinders with a large clear sound tube in the center. They are to be inserted over the OAE Probe cover tip, conical part of the probe. To place in the ear, roll the tip to reduce the foam size, place in the ear canal, then hold in place to let it expand. It may be helpful to pull slightly down and back on the ear lobe to make the ear canal more accessible.



Reducing noise for AEP acquisition

Auditory Evoked Potential are very small electrical signals measured in the microvolt range, which is one-millionth of one volt. Due to the small amplitude of the signals, they are highly susceptible to external noise contaminants. The following is a list of recommendations to reduce noise for AEP testing in general, these can also be applied to any other evoked potentials. Try to implement as many of these as possible, always keeping patient safety as the first priority.

- Make sure all the equipment is connected to the same earth ground. This includes all non-IHS equipment electrically connected to the computer. All non-grounded connections should be removed before starting acquisition. Network computers may need to be disconnected from the network while acquiring.
- Non-essential monitors or equipment connected to the patient should be turned off or disconnected from the patient if possible. Get physician or hospital approval before disconnecting any equipment. Never disconnect essential equipment from the patient.
- Try to avoid the use of heating pads, cooling pads, or any other electrical devices where the patient is located. Chairs or beds with electrical motors may need to be turned off. Devices that use wireless technology (such as Bluetooth) should be turned off.
- Keep any and all electrical cables away from electrode leads. Any cables crossing the leads may cause artifacts or recording noise.
- If using individual electrode leads, braid the electrode leads together to reduce possible antenna effects and electromagnetic interference.
- Keep CRT monitors away from the electrode leads.
- Never use expired disposable electrodes, expired conductive paste, or visibly compromised electrode leads.
- When testing babies, try to minimize suckling movement since it will cause muscular artifacts. Babies will generally be quiet a few minutes after feeding.
- Slight changes in the rate of acquisition may cause some noise components to minimize and sometimes disappear as the average is accumulated. Large changes in the rate may also reduce the noise, but could result in a very different wave morphology, diminishing some peaks while accentuating others.

Patient state for AEP recordings

The following are some general guidelines for the state of the patient while acquiring responses.

- For most AEP acquisition, such as ECochG or ABR, the patient should be in a relaxed state. The patient does not need to sleep, although it helps.
- Laying down is better than sitting, since muscle tension in the neck area can lead to post-auricular muscle artifacts (PAM) that will affect the recording, especially during ABR acquisition.
- Newborn babies are easier to test shortly after feeding.
- Patients should avoid stimulants such as caffeine, or any drugs that may hinder normal nervous system behavior; if the use of such drugs is unavoidable, make sure to take this into consideration when evaluating the acquired responses.
- Sedation, even for infants, is not necessary, although some users will favor it. Only properly trained personnel should use sedation.

Recordings requiring patient attention

There are some exceptions to having the patient relaxed; like

- P300, where the patient must be conscious and pay attention to odd stimuli. Sitting is the most optimal position for P300, as laying down may cause patient to relax too much and stop paying attention, even fall asleep.
- VEP acquisition requires visual stimulation so the patient must also be awake and sitting in an upright position.
- For Somatosensory testing the patient will generally be sitting upright as well, in this case, the patient should be advised of the sensation the electrical stimulus may cause so that they are not unpleasantly surprised when the stimulation starts.

Parameters for Acquisition

6

Modifying testing parameters

Control panel settings

The most commonly modified testing parameters are easily accessible from the SmartEP control panel. The suggested values for these parameters are found later in this section.

- The **[Ear]**, **[Mode]**, and **[Phase]** can be changed by simply left or right-clicking on the button; these buttons rotate through their list of values when clicked.
- The **[Intensity]** and **[Rate]** buttons will decrease by a value of 10 when left clicked and increase by 10 when right clicked.
- The **[Sweeps]** and **[Time]** buttons will double in value when right clicked, and half in value when left clicked.

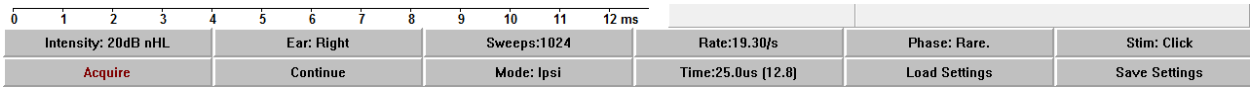


Figure 6 - SmartEP Control Panel

Some modalities, such as P300, will have some of the buttons replaced with other functions to accommodate for the different settings needed. Refer to those individual sections for additional details about the mode-specific settings and functions.

Understanding Time and Scale

The **[Time]** value defines the time distance between samples in the recorded response. If the Time value is set to 25.0 µs, then a sample will be taken every 25 microseconds. Given that each recording in SmartEP has 1024 data points, and half of those data points are part of the post-stimulus recording region, the post-stimulus period of the recording will span 12.8 milliseconds (25 µs x 512 samples, as shown in parenthesis in the **[Time]** button). In that same manner, if the time setting is doubled (50.0 µs), then the new plot end will be 25.6 ms.

Generally, this setting will be changed automatically to an appropriate value when choosing the acquisition mode, making manual changes to this value rarely necessary. When changed, the value of the **[Time]** button will also modify the horizontal scale of the page automatically.

Figure 7 - Time button showing sample time and post stimulus period

As a rule of thumb, make the Time (µs) value a little more than double of the amount of data needed, rounding up at least to the next multiple of 25. For example, if there is a need for 80 ms of post-stimulus data, make the Time value at least 175; that is to say double the value (160) rounded up to the next 25 µs increment, where 25 µs is the minimum step size for this value.

If the time setting is changed after there are some recordings on the page, the recordings will either get trimmed if the plot time is reduced or shrunk if the plot time is extended. Changing the time setting after acquisition will not modify a recording or it's resolution, only the region displayed. To change the scale after changing the time setting, use the **[Plot Start]** and **[Plot End]** parameters on the **[Set Page]** pop-up menu located at the right of the screen.

Saving settings files

Once all settings are defined, the acquisition settings can be saved to a file for later use. Simply click on the **[Save Settings**] button at the bottom right-hand side of the control panel. If the settings will be used commonly, keep the name of the file as 'SEPWIN.SET'; this will cause the settings to load at start-up. Otherwise, make sure to give the settings file a descriptive name. Always keep all settings files to be used in the 'Settings_EP' folder. As a precaution, it is a good idea to make a backup of this folder once you have defined settings files.

Choosing the stimulus

The stimulus options can be accessed by clicking on the **[Stim]** button from the Control Panel, opening the Auditory Stimulus Generation window. This window contains all options related to the stimulus output.

Figure 8 - Stimulus Button showing Click as the currently selected stimulus

Stimulus types

Stimulation types include click, tones, and files.

- Click stimulation should be defined in microseconds, in increments of 25. A 100 microsecond click is the most commonly used click duration.
- When choosing Tone Burst, the duration can be entered in cycles or in microseconds. Some users will find it easier to choose the duration in cycles since many articles and books refer to stimulus durations measured as "Rise-Plateau-Fall" ratios. E.g., if there is a need for a 2-0-2 ratio, the total number of cycles is 4; if there is a need for a 2-1-2 ratio, the total number of cycles is 5. Note that this field only defines the total duration, while the 'Rise/Fall Time' field, found in the envelope section of the window, will define the structure to achieve the desired ratio.
- Files can be selected from all available "STM" files in the 'Stim_EP' folder of the main software installation directory, typically "C:\IHSProgs\Stim_EP". Files can include defined stimuli saved from this window, using the **[Save]** button, stimuli created using the Stimulus Generation utility, or 'WAV' sound files converted to 'STM' using the Stimulus Converter utility. Instructions for creating 'STM' files and calibrating them can be found at the end of this section, and in the Launch Pad manual.

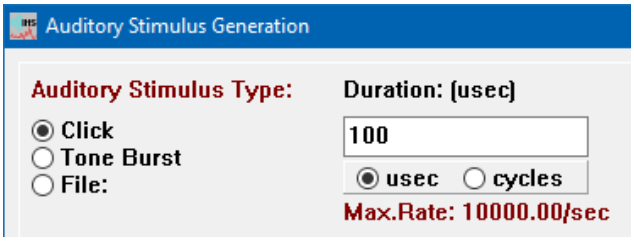


Figure 9 - Stimulus Types

Stimulators

The stimulator selector defines the output device to be used for stimulus delivery. The list can be found on the left-hand side of the window. Grayed-out list items cannot be selected and are either not available for the current platform or are not installed in the active hardware.

Make sure to choose the correct stimulator from the list, doing so will ensure accurate sound output levels. Note that some stimulators have multiple listings, where they differ in the type of patient coupler. These options compensate for the different cavity sizes resulting from the use of these couplers, since the cavity size affects the acoustic performance of the stimulator.

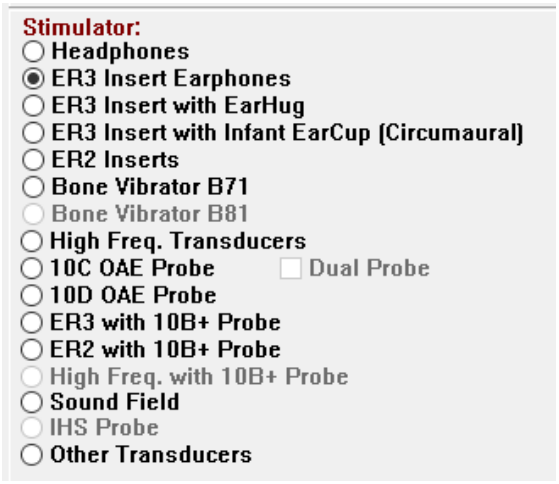


Figure 10 - Stimulator List

Envelopes

Envelopes help transform a Pure Tone sound into a Tone Burst. They shape the ramp-up/ramp-down of the stimulus, helping to elicit a more robust response. Generally, a Blackman envelope is used as it elicits the strongest AEP responses.

Only the Trapezoidal and Extended Cosine envelope options require a rise/fall time value; by definition, all others have a plateau of 0, making their rise/fall time exactly half of the stimulus duration. For an extended description of the envelopes, see the button and menu reference of this manual.

When choosing the Gaussian envelope, the duration field will be restricted to cycles. These should be specified in increments of 0.5 to achieve a smooth transition to zero amplitude.

Click stimulation and "STM" files are not affected by this setting; when using either of those stimulus types, the envelope will be automatically set, and locked to, Rectangular.

Figure 11 - Stimulus Envelopes

Masking

Masking is used to procure additional sound, generally white noise, to the contralateral ear (opposite to the one being tested) when using a bone conductor. Setting the masking as **[Specific]** and checking the **[Contralateral]** check box will allow you to enter a fixed value for masking. When setting the masking as **[Tracking]**, the value entered will instead apply as an offset intensity value which will follow the intensity set for the actual stimulus (in the control panel). Note that masking levels are always in dB SPL, regardless of stimulus scale used.

Tracking masking guidelines

Total masking needed will depend on the type of stimulator used. Each type of stimulator has an inherent inter-aural attenuation that must be taken into consideration when applying masking; when used in combination with the effective masking, it helps determine the most appropriate masking level.

- **Bone Conduction**: When using bone conduction, masking provides the only way to discern between the responses of one ear and the other. Bone conduction has an average of 0 dB inter-aural attenuation. Given that an effective masking level of 40 is needed, then when using the tracking option, enter '40' in the masking value field. Example, a bone conduction stimulus at 50 dB HL will require a masking of 90 dB SPL
- **Insert Earphones**: When using inserts, masking can help to differentiate the responses of left and right in cases where there is an asymmetric hearing loss; in all other cases, masking will not have any significant effect. Insert earphones have an inter-aural attenuation of 60 dB. Given that an effective masking of 40 is needed, then when using the tracking option, enter '-20' in the masking value field. Example, an insert earphone stimulus at 80 dB HL will require a masking of 60 dB SPL.
- **Headphones**: When using headphones, masking can help to differentiate the responses of left and right in cases where there is an asymmetric hearing loss; in all other cases, masking will not have any significant effect. Insert earphones have an inter-aural attenuation of 40 dB. Given that an effective masking of 40 is needed, then when using the tracking option, enter '0' in the masking value field. Example, a headphone stimulus at 70 dB HL will require a masking of 70 dB SPL.

Some procedures may call for Ipsilateral masking, providing white noise with a notch at specific frequencies, this is only possible on the USB Box and Duet systems with additional hardware added; this option will be grayed out if it is not available for the current unit.

It is also possible to reverse the masking and stimulator by turning on the **[SAL]** check box (Sensorineural Acuity Level), outputting the stimulus from the inserts while the masking is provided by the bone conductor.

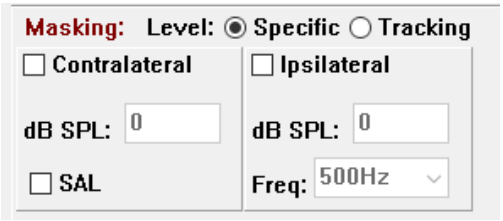


Figure 12 - Masking Options

Stimulation mode

The modality of stimulation will determine whether the Intensity button in the control panel shows values in SPL or in HL.

Figure 13 - Stimulus Mode Options and the Intensity Button

About SPL, HL, and nHL

These 3 scales can be used to describe the stimulus intensity output. They are given in decibels, in reference to a standard pre-defined level.

- **SPL**: The SPL scale defines the output in terms of measurable Sound Pressure Level. The reference value for this scale is defined by the ANSI organization. The decibel reference value, or 0 dB, is defined as 20 micro pascals (μP RMS). To put the decibel scale in perspective, a 20 dB sound is 10 times as loud as a 0 dB sound, or 200 micro pascals. SPL values can be measured using a device called Sound Pressure Level Meter, sometimes referred to as SLM. Equipment is calibrated using the SPL scale.
- **HL**: The HL scale defines the output in terms of Hearing Level. This scale is a modified version of the SPL scale to accommodate for human hearing level and brings pure tone thresholds to a uniform value across the frequency range. By the definition of this scale, 0 dB is the value at which tonal hearing threshold occurs in normal hearing, young, individuals. SPL values can be converted to the HL scale using a simple conversion value that applies to the specific frequency of the tone. In brief, this scale equalizes the hearing sensation level of pure tones to a scale where 0 value is the hearing threshold. The SmartEP program contains a built-in SPL-to-HL conversion table.
- **nHL**: The nHL scale refers to sound in terms of Normal Hearing Level. This scale applies to the hearing threshold of normal hearing individuals for clicks or brief tone stimuli. It mirrors the concept of HL but applies to Tone Bursts (short duration) rather than Pure Tones (long duration). The required nHL conversion value (from SPL) will vary depending on the structure of the Tone Burst. To achieve this in SmartEP, save the stimulus file first, as described below, and then use the Stimulus Calibration Utility to define its unique SPL-to-HL conversion value.

Calibration

The system calibration for the selected stimulus is shown at the bottom right-hand side of the window. Values are shown for information purposes only. Shown are the values in **[SPL]** or **[SPL + SPL-to-HL]** depending on the stimulation output mode. It is also possible to access the full SPL calibration table, SPL-to-HL correction table, and file calibration values from the corresponding adjacent buttons.

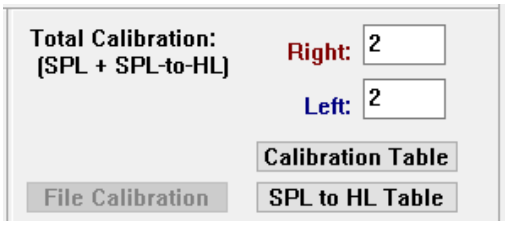


Figure 14 - Calibration Panel

Saving stimulus files

Once all your stimulus parameters are set, it is possible to save them to a file for future use. To do it, simply click on the **[Save]** button and give the file a good descriptive name. Note that you do not need to save the file to use the set stimulus; simply clicking **[OK]** will activate the current selection. Saved stimulus files must be calibrated before use. The files can be calibrated specifically or can be calibrated relatively to the system calibration.

Selecting filters and gain

Filters determine which part of the incoming EEG signal is allowed to average into the response. Required filters will change based on the type of response that is being acquired. ABR responses, for example, are composed of higher frequency energy when compared to that of a LLR response. The frequency composition of responses may also vary with patient age or type of population. Having the right filters is important, or the important information may end up being filtered out of the average.

Gain determines how much the recording is amplified before averaging. The gain value should vary according to the type of response being acquired. An ECochG response, for example, is in the microvolt range and requires

high amplification; where a P300 response is in the millivolt range and will require much less amplification. Having the correct amplification value will prevent the recording from either becoming undetectable from too low a setting, or from saturating the amplifier from too high a setting.

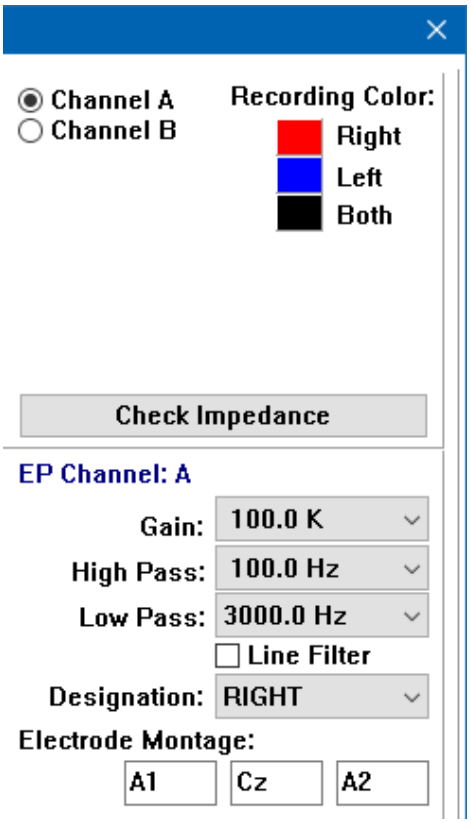


Figure 15 - Amplifier Gain and Filter Settings

Setting hardware filters

For most cases, the correct filters and gain values will be set automatically when switching acquisition modalities. To modify the settings:

1. Open the Amplifier window by clicking on the **[Amplifier]** button from the SmartEP side panel.
2. The channel selection, filter setting, and gain settings are located on the right side of the window. Select the channel first using the radio buttons, then change the filter settings as needed; make sure to change the settings for all channels to be used during acquisition, as all channels have independent values. The filters in these settings are hardware based and have an attenuation value, see the USB Technical reference manual for actual attenuation values.
3. Click **[OK]** to commit the changes to the filters and gain.

The Line Filter (notch filter) check box should remain unchecked unless it is needed. This setting will activate an additional level of filtering to reduce the effects of excessive power line noise on the recordings. This filter is custom made for your location's line power frequency, be it 50 or 60 Hz.

Although the Amplifier window can remain open during acquisition, settings changes will not be applied until the **[OK]** button is clicked. Settings will not change if SmartEP is in the middle of data acquisition, they will only apply to the next acquisition.

Automated digital filtering

Automatic digital filtering is possible for incoming recordings. However, using this feature is not recommended in most cases as recordings could end up being over-filtered, losing data definition. When this setting is active, incoming recordings will be filtered as they are acquired and any data loss due to the severity of the filters will

be unrecoverable. A better option is to acquire without it, and then perform post-acquisition filtering, which is non-destructive since the original data has already been saved. If you still want to use this feature, activate it by choosing **[Amplifier > Digital Filter]** from the SmartEP main menu. The option is active when there is a check mark next to it. To modify the digital filters, change their values under **[Amplifier > Digital Filter Settings]** in the main menu.

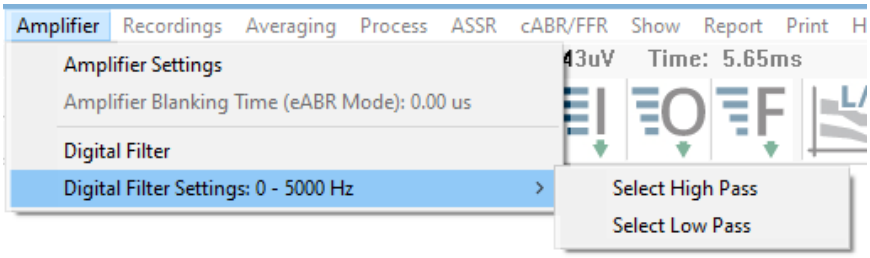


Figure 16 - Digital Filter Options in the System Menu

Hardware filters vs. digital filters

Hardware filters: This filter is based on physical components inside the hardware box. The filter has a slope, increasing its effectiveness for frequencies farther outside the filter limits. Influence from the frequencies outside the filters is still present, but greatly diminished.

Digital filters: This filter is based on the Fourier Transform (FFT) of the signal performed in software. The filter is a full cutoff, where frequencies lower than the cutoff for high-pass, or higher than the cutoff for low-pass will be eliminated completely, no residual influence is left.

Artifact rejection

The rejection region and rejection level settings will determine what sweeps are allowed to be added into the average and which are rejected. It is better to reject sweeps containing muscular artifacts or other high-level noise as they can harm an average and sometimes make it unusable. The settings can be found in the Amplifier window and are channel independent. To adjust them:

1. Open the Amplifier window by clicking the **[Amplifier]** button from the SmartEP side panel.

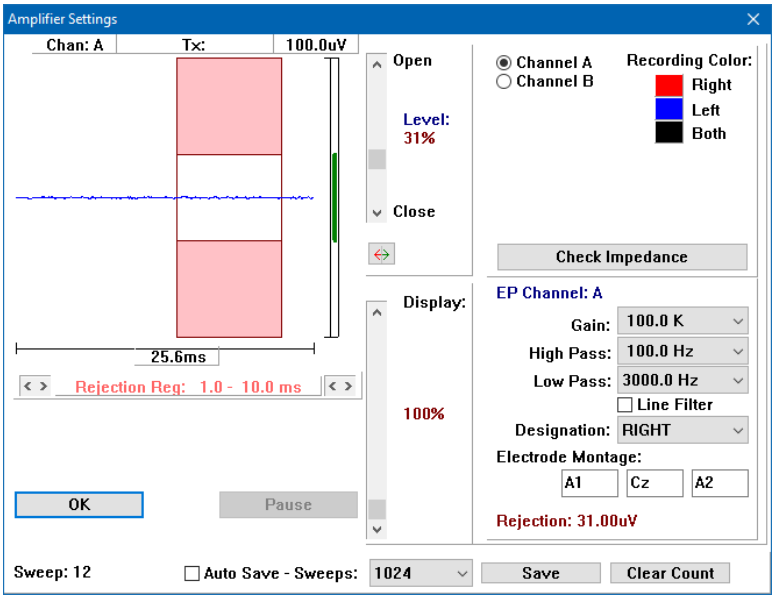


Figure 17 - Amplifier window showing the rejection area.

2. Move the **[Level]** slider up or down to adjust the rejection level. This value is shown in percentage next to the slider; the actual microvolt value can be seen at the bottom right of the window labeled as

'Rejection'. Moving the slider all the way up to 100% (Open) will cause all sweeps to be accepted, while moving it all the way down to 0% (Closed) will cause everything to be rejected. A level of about 30% is usually sufficient for most acquisitions.

3. The rejection start and end time can also be adjusted by clicking on their respective adjustment buttons at the bottom of the live EEG graphic. This setting rarely needs to be modified since the applicable settings will be automatically loaded when changing acquisition modalities. In general, the rejection region should be set to cover the post stimulus region, accounting for any stimulus ringing that may occur, while trying to cover the entire region of the expected repeatable response. Figure 17 shows the rejection region spanning from 1 ms to 10 ms, the most common setting for ABR.
4. Click **[OK]** to close the window and commit your changes.

As with the filters and gain settings, the **[OK]** button needs to be pressed for changes to take effect; closing the window with the **[X]** button will cancel any changes made to the settings. These parameters cannot be changed in the middle of an acquisition run and will only apply the next time the **[Acquire]** button is pressed.

Block Acquisition and Averaging

Block acquisition will allow the averaging of the recorded waveform post-acquisition. A waveform acquired using blocks can have its averaging method changed to Weighted, Median, or EMG average. Block acquisition also allows for the calculation of Fsp and Fmp measures. This feature must be turned ON before acquisition is started to be able to use these averaging options. To do so click on **[Averaging > Block Averaging Method]** to open the submenu and choose the averaging type, then choose an option for the number of sweeps per block from the **[Block Averaging]** option. Some things to keep in mind

- Pay attention to the total number of sweeps for your acquisition when using this option, e.g., if the total number of sweeps will be 100, then choosing a block size of 100 will only save a single block.
- If choosing a number of sweeps that is not a multiple of the block size, the acquisition will round the number of sweeps upward; where, if choosing 50 sweeps and a block of 20 will result in a 60 sweeps recording.
- Once a block averaging option is selected, the live average can be switched to a different averaging mode while the recording is being acquired. The waveform will change the plot to the new averaging method as needed.
- Use **[Block Averaging Phasor Display]** option in the Averaging menu to show a graph below the EEG panel on the bottom right-hand side of the screen. Press the **[EEG]** button if the panel is not already open. See Analysis of block averaged waveforms on page 54 for more details about this graph.
- Recordings made using block acquisition will be marked as '**wBLOCKS'** on the data file list.

Suggested acquisition parameters

The following sub-sections show suggested acquisition parameters for the different types of AEP recordings that can be obtained using SmartEP. Refer to the respective manual sections for: Somatosensory, Visual, and other types of acquisition not listed in this section. These settings are starting points based on standard clinical test batteries. Consult the literature, then modify the parameters and electrode montage as needed to meet your acquisition goals. Adjust the settings accordingly for situations where there is excessive ambient noise, or when the patient has special needs.

ECochG settings

Before changing any settings, change the software modality to ECochG by choosing **[Protocol > Modality > Auditory > ECochG]** from the SmartEP main menu.

- Stimulus Type: Click.
- Stimulus Duration: 0.1 millisecond.
- Stimulator: Insert Earphones.
- Intensity: 90 or 95 dB HL.
- Rate: 7.1/sec. or 99.9/sec. Use slow rates to enhance AP, fast rates to differentiate SP from AP
- Polarity: Alternating.
- Line Filter: OFF. Only turn ON if there is excessive electrical line noise.
- Gain: 75x or 100x.
- Low Pass Filter: 1500 Hz.
- High Pass Filter: 10 Hz or 1 Hz.
- Sweeps: 250 to 500.
- Analysis Time Window: 0 to 5 milliseconds.
- Electrode Montage: Horizontal Array.

Due to the limited amplitude of the waveforms, ECochG acquisition requires the use of especial electrodes.

- Gold Foil Tip-Trodes are standard foam ear-tips covered in conductive gold foil, they serve as an ear-tip and electrode at the same time. They are attached to the Opti-Amp using a special electrode lead with an alligator clip at the end.
- TM-Wick electrodes are small electrodes that are placed directly at the tympanic membrane, making contact using a conductive gel. Wick electrodes are secured in place by the foam ear tip, so they need to be placed first or simultaneously with the foam tip.

Keep in mind that using different electrode types will change the morphology of the waveform due to the differing distances to the generator sites, changing also the relation and amplitude ratio between SP and AP.

Click ABR settings

Before changing any settings, change the software modality to ABR by choosing **[Protocol > Modality > Auditory > ABR]** from the SmartEP main menu.

- Stimulus Type: Click.
- Stimulus Duration: 0.1 millisecond.
- Stimulator: Insert Earphones or Headphones.
- Masking: optional, only needed for asymmetric hearing losses. Tracking option set to '-20' when using insert earphones, set to '0' when using headphones.
- Intensity: 80 to 95 dB HL for neuro-diagnostic. 70 dB HL to start then up or down for threshold search.
- Rate: 27.7/sec. Slower rates tend to enhance wave I.
- Polarity: Rarefaction provides clearest wave I. Use condensation if response is not optimal. Use Alternating if there is excessive stimulus artifact at the start of the waveforms.
- Line Filter: OFF. Only turn ON if there is excessive electrical line noise.
- Gain: 100x.
- Low Pass Filter: 1500 Hz for infant ABR. 3000 Hz for adult ABR.
- High Pass Filter: 30 Hz for infant ABR. 100 Hz for adult ABR.
- Sweeps: 1000 to 2000.
- Analysis Time Window: 0 to 12 milliseconds.
- Electrode Montage: Ipsilateral or Contralateral Array.

Bone conduction ABR

Before changing any settings, change the software modality to ABR by choosing **[Protocol > Modality > Auditory > ABR]** from the SmartEP main menu.

- Stimulus Type: Click or 500 Hz Blackman tone.
- Stimulus Duration: 0.1 millisecond click, 5 cycles for Blackman tone.
- Stimulator: Bone Vibrator.
- Intensity: 60 dB HL maximum, down to 0 HL for threshold search.
- Masking: Recommended, tracking option set to '40'.
- Rate: 7.1/sec. Slower rates tend to enhance wave I, revealing a more ear-specific response.
- Polarity: Alternating.
- Line Filter: OFF. Only turn ON if there is excessive electrical line noise.
- Gain: 100x.
- Low Pass Filter: 3000 Hz for adults, 1500 Hz for infants.
- High Pass Filter: 30 Hz.
- Sweeps: 1000 to 2000.
- Analysis Time Window: 0 to 12 milliseconds.
- Electrode Montage: Ipsilateral or Contralateral Array.

Although masking is recommended, it is not usually necessary for determining the source of the response. If wave I is present, since wave I is always a near-field response, then the response is ipsilateral. Remember to keep the bone conductor cable away from the electrode leads to minimize noise

Tone Burst ABR settings

Before changing any settings, change the software modality to ABR by choosing **[Protocol > Modality > Auditory > ABR]** from the SmartEP main menu.

- Stimulus Type: Tone Burst.
- Stimulus Duration: 8 ms for 500 Hz, 4 ms for 1 kHz and higher frequencies. That is equivalent to a minimum of 4 cycles, or a 2-0-2 duration ratio.
- Envelope: Blackman.
- Stimulator: Insert Earphones or Headphones.
- Intensity: 80 to 95 dB HL for neuro-diagnostic. 70 dB HL to start, then up or down for threshold search.
- Masking: optional, only needed for asymmetric hearing losses. Tracking option set to '-20' when using insert earphones, set to '0' when using headphones.
- Rate: 27.7/sec. or 38.5/sec. Slower rates tend to enhance wave I.
- Polarity: Use condensation for 500 Hz. Use Alternating for 1 kHz and higher frequencies.
- Line Filter: OFF. Only turn ON if there is excessive electrical line noise.
- Gain: 100x.
- Low Pass Filter: 1500 Hz.
- High Pass Filter: 30 Hz.
- Sweeps: 2000.
- Analysis Time Window: 0 to 25 ms for 500 Hz. 0 to 12 ms for 1 kHz and higher frequencies.
- Electrode Montage: Ipsilateral or Contralateral Array.

MLR settings

Before changing any settings, change the software modality to MLR by choosing **[Protocol > Modality > Auditory > MLR]** from the SmartEP main menu.

- Stimulus Type: Click for neuro-diagnostic. Tones for audiometry.
- Stimulus Duration: 0.1 millisecond if using clicks. 2-1-2 duration ratio for tones.
- Envelope: Blackman.
- Stimulator: Insert Earphones.
- Intensity: 70 dB HL. Larger intensities may result in post-auricular muscle artifact. Use intensities down to 0 HL for threshold search.
- Masking: Only if stimulus will exceed 70 dB HL. 50 dB Contralateral (Tracking option set to '-20').
- Rate: 7.1/sec.
- Polarity: Alternating.
- Line Filter: OFF. Only turn ON if there is excessive electrical line noise.
- Gain: 75x.
- Low Pass Filter: 200 or 1500 Hz.
- High Pass Filter: 10 Hz.
- Sweeps: 1000.
- Analysis Time Window: 0 to 50 milliseconds.
- Electrode Montage: Ipsilateral or Contralateral Array.

LLR settings

Before changing any settings, change the software modality to LLR by choosing **[Protocol > Modality > Auditory > LLR]** from the SmartEP main menu.

- Stimulus Type: Tones. 500 Hz to 8000 Hz, as needed.
- Stimulus Duration: 40 ms.
- Envelope: Blackman.
- Stimulator: Insert Earphones.
- Intensity: 50 dB HL or higher.
- Masking: None.
- Rate: 1.1/sec.
- Polarity: Alternating.
- Line Filter: OFF. Only turn ON if there is excessive electrical line noise.
- Gain: 50x.
- Low Pass Filter: 30 Hz.
- High Pass Filter: 1 Hz.
- Sweeps: 250.
- Analysis Time Window: 0 to 600 milliseconds.
- Electrode Montage: Ipsilateral or Contralateral Array.

40 Hz settings

Before changing any settings, change the software modality to MLR by choosing **[Protocol > Modality > Auditory > MLR]** from the SmartEP main menu.

- Stimulus Type: Special File. The file named '40Hzresp.STM' is included in the 'Stim_EP' folder. The file contains four consecutive clicks with a 25 ms ISI.
- Stimulator: Insert Earphones.
- Intensity: 80 dB HL down to 0 HL for threshold search.
- Rate: Around 10/sec.
- Polarity: Rarefaction.
- Line Filter: OFF. Only turn ON if there is excessive electrical line noise.
- Gain: 100x.
- Low Pass Filter: 300 Hz.
- High Pass Filter: 10 Hz.
- Sweeps: 500.
- Analysis Time Window: 0 to 200 milliseconds.
- Electrode Montage: Ipsilateral or Contralateral Array.

Cochlear microphonic settings

Use similar settings as for ABR recordings; however, it must be acquired using Alternating phase (and then shown as a Split-Sweep average); or by performing two acquisitions, one in rarefaction and one in condensation, with all other settings remaining the same (then superimposing the waveforms).

Creating stimulus files

Special stimulus files may need to be created for certain types of acquisition, or when a particular calibration or correction is needed. Stimulus files can be generated by using the **[Save]** button on the Auditory Stimulus Generation window. They can also be created by converting a WAV format sound file to the STM stimulus format used by SmartEP. In both cases, the stimulus will need to be calibrated before use.

Saving a Stim file from SmartEP

1. Open the Auditory Stimulus Generation window by clicking on the **[Stim]** button on the SmartEP Control Panel.
2. Select the options you wish to use for the stimulus file, including frequency, duration, and rise/fall time if applicable.
3. Click on the **[Save]** button at the bottom of the window.
4. Calibrate the stimulus using the Stimulus File Calibration utility as described in the Launch Pad manual

Converting a WAV file to Stim

1. Open the Stimulus Conversion Utility from the Launch Pad Program, **[Utilities > Stimulus Converter]** in the Launch Pad main menu. The utility is also accessible from the Auditory Stimulus Generation window.
2. Select the WAV file to be used as the source by clicking on the **[Browse]** button next to the field.
3. Select the destination STM file by clicking on the **[Browse]** button next to the Target field. To work properly, stimulus files must be saved to the 'Stim_EP' folder in the programs installation directory. Alternatively, you can save them to another location and then copy them over to the stimulus files folder. Make sure to enter a name that is descriptive enough to remember the contents of the STM file.
4. Use the 'Smooth', 'Demean', or 'Remove DC' check boxes if needed. Smooth can be used to remove cracking noises or high frequency components. Demean will prevent the sound from clipping if its volume is too high. Remove DC will remove any offset found in the initial level of the wave.
5. The output sampling for SmartEP is 40 kHz. Using the **[Allow < 40 kHz]** sampling rate should only be used when converting for stimulus longer than 0.5 secs for use in a different application or for use with the Auditory Research Module while lowering the system base sampling rate.
6. Click on the **[Go!]** button to complete the conversion.
7. Calibrate the stimulus using the Stimulus File Calibration utility as described in the Launch Pad manual or your hardware platform's Instructions for Use documentation.

Important things to keep in mind when converting wave files to STM:

- The converted stimulus can only be 0.5 seconds long, the maximum allowed by standard SmartEP. Wave files longer than this will be clipped to that length when converted. Anything longer requires lowering the System Base sampling rate or using extended stimulus files; these functions are only available to users of the Advanced Auditory Module; refer to the Launch Pad manual or your hardware platform's Instructions for Use documentation for details.
- When generating or editing a wave file for conversion, try to have the sound fall back to zero amplitude at the end of the file; non-zero ending values may result in an added click sound at the end of the stimulus.

Data Acquisition

7

Starting acquisition

To start acquisition, simply click once on the **[Acquire]** button at the bottom left-hand side of the SmartEP control panel. After pressing the button, it will change to read **[Stop/Pause]**.

Figure 18 - Acquire button in the SmartEP Control Panel

Pausing and stopping acquisition

When acquisition is started, the acquire button will change to a **[Stop/Pause]** button. Press the button to pause the acquisition. Although the acquisition process will be paused, stimulation will continue, and the screen will refresh constantly even though sweeps are not being added to the average.

A confirmation screen will pop-up asking if you would like to continue with acquisition. Clicking on the **[Yes]** button will continue with the averaging, while clicking **[No]** will stop the acquisition process.

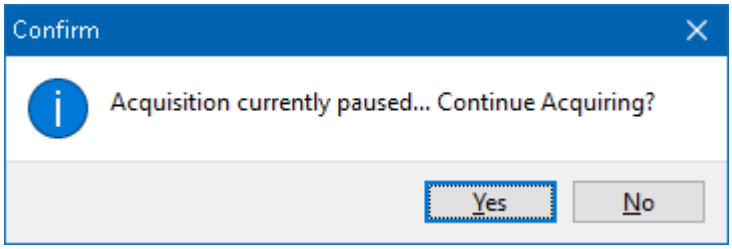


Figure 19 - Stopping Confirmation

Extending acquisition

It is possible to add more sweeps to a recording after it has finished acquiring. To do this,

1. Increase the number of sweeps to the total number you want; this number must be higher than the number of sweeps already averaged for the selected recording.
2. Then, with the recording selected and the parameters still the same, click on the **[Continue]** button on the SmartEP control panel.

A new recording will be created and will average additional sweeps onto the existing average until it reaches the new sweep count. Make sure to keep the parameters the same as with the original recording, or averaging will not continue. If the number of sweeps is not increased manually, clicking on the **[Continue]** button will automatically double the number of sweeps currently shown on the **[Sweeps]** button.

Automating acquisition with protocols

A protocol is a file containing a list of instructions to be executed by SmartEP in an automated fashion. These can be useful for defining testing sets that are always done in sequence, such as a threshold search. Although protocols can be run unattended, it is always a good idea to monitor the progress for situations such as when an electrode falls off.

Creating an automated protocol

In this example we will create a protocol for Click ABR acquisition at 3 different intensities. To create the protocol:

1. From the SmartEP main menu, click on **[Protocol > Setup Automated Protocol]**.
2. The Protocol Setup window will open. Most options in the window will be grayed out, until the first item is activated.
3. To activate the first item, enter '2' in the **[Count]** field. This means that Item 1 will execute twice.

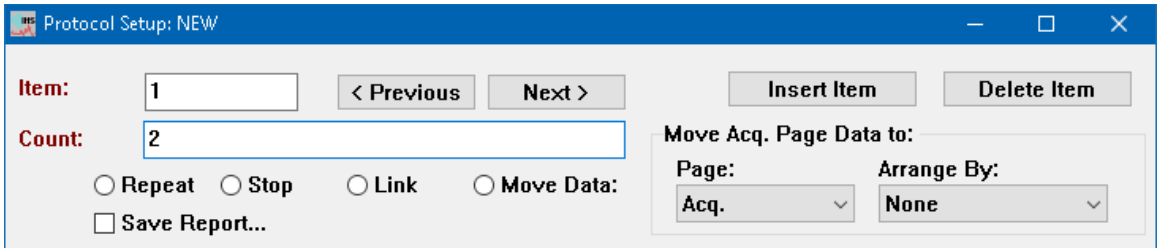


Figure 20 - Protocol Setup window Item and Count

4. Leave the **[Ear]** as 'Default' so that the protocol can be used for both ears. Leaving items as default means that the protocol will use the Control Panel value.
5. Click on the **[Stimulus]** check box to open the Auditory Stimulus Generation window. Select **[Click]** as the stimulus type, **[ER-3 Inserts]** as the stimulator, and set the mode to **[HL]**. When done, click **[OK]** to confirm the selections. Note that the stimulus option will now have a check mark with a small description of the selected stimulus.
6. Click on the **[Intensity]** check box and enter the value '70'.
7. Leave the rest of the settings as default. When set to default, the protocol will take the current values set in the SmartEP control panel at the time of execution, making the protocol very flexible.

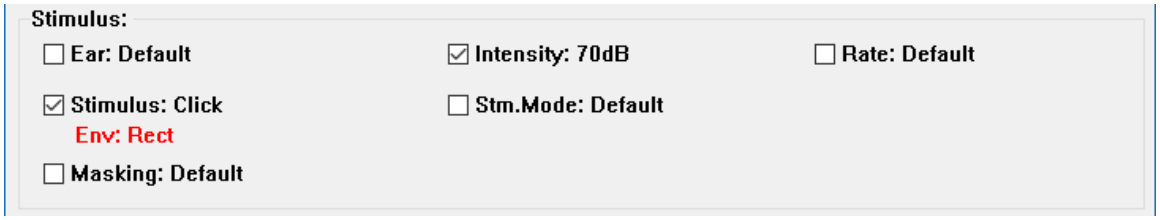


Figure 21 - Protocol Setup window stimulus options

8. Click on the **[Next]** button at the top of the window to move to the next item.
9. Activate the second item by entering '2' in the **[Count]** field. Item 2 will execute twice as well.
10. Click again on the **[Stimulus]** check box. Since we will not be changing anything from the stimulus selected in item 1, just click the **[OK]** button to confirm.
11. Click on the **[Intensity]** check box and enter the value '50'.
12. Click on the **[Next]** button at the top of the window to move to the third item.
13. Activate it by entering '4' in the **[Count]** field. We want to confirm the peaks are there if found, so this will execute the third item four times.

14. Check the **[Stimulus]** box again and confirm the stimulus. This time enter the value of '30' for the intensity.
15. Now that we are done entering items, click the **[Save]** button and give your protocol a descriptive name such as "**70-50-30-Click.PSE2**".
16. Click the **[OK]** button to close the Protocol Setup window.

With the file saved, the protocol is ready to be used. Note that new protocol files use the extension "**.PSE2**", older protocol files will have the extension "**.PSE**". SmartEP is backwards compatible, so old protocol files can still be used.

Executing a protocol

Now that the protocol has been created, it can be used for acquisition. In this example we will use the file created in the previous section.

1. In the control panel, select 'Right' for the **[Ear]**, leave the **[Mode]** as 'Ipsi', **[Phase]** as 'Rarefaction', **[Sweeps]** as '1024', and **[Rate]** as '19.30/s'. Adjust the Amplifier settings if necessary.
2. From the main menu, click on **[Protocol > Execute Automated Protocol]**.
3. Select the protocol that was saved on the previous section from the list of files then click the **[Open]** button to start running it.
4. Once the run completes, there will be two recordings at 70 dB, two recordings at 50 dB , and four recordings at 30 dB.
5. To continue with the opposite ear, change the **[Ear]** setting on the control panel to 'Left', keep all other settings the same, then execute the protocol again. Remember that on the example, we kept the ear setting as default, allowing changes to be made to the run by using the settings on the control panel.
6. Once it finishes, the recording area should contain a set of recordings for the left and the right ears.

Pausing or stopping protocols

If by any reason the protocol needs to be stopped, or temporarily suspended, click on the **[Stop/Pause]** button as you would when stopping a single recording. A window will pop-up asking if you wish to continue acquisition.

- Clicking **[Yes]** will continue the acquisition and the protocol normally.
- Clicking **[No]** will stop this recording.

A second window will ask if the protocol should be continued or stopped.

- Clicking **[Yes]** will continue with the next recording in the protocol (next item, or item repetition depending on when the protocol was interrupted.)
- Clicking **[No]** will stop protocol execution completely.

Assessing waveforms

Waveform Repeatability

When acquiring an AEP response, it is expected that a good waveform will be repeatable, since this is the characteristic that qualifies the waveform as a true response to the stimulus. In most sessions, it is recommended to acquire at least two waveforms using the same parameters; when superimposed, waveforms will generally show a very similar structure.

Cross-Correlation

This objective measure can help determine repeatability between two waveforms. Follow the steps in Cross-correlating two recordings on page 67.

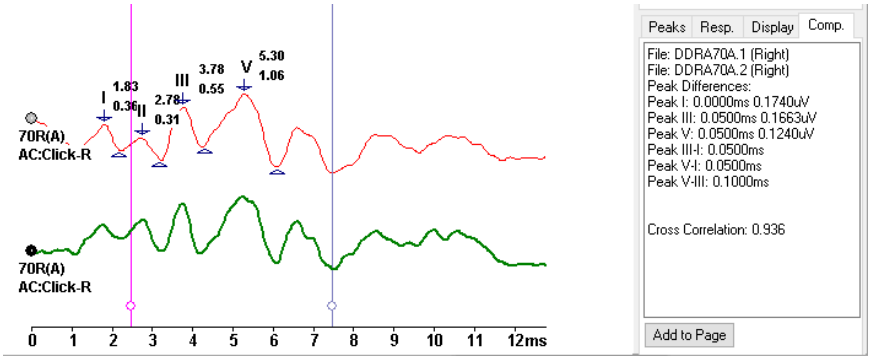


Figure 22 - Cross Correlation of two waveforms

Self-Cross-Correlation

In some cases, where acquiring a second waveform is not feasible, it is still possible to assess repeatability by looking at the value of self-cross-correlation for the waveform or showing the waveform in split sweep format. To see the value of self-cross-correlation open the recording information panel by pressing the **[Rec Info]** button on the right side of the screen.

Analysis of block averaged waveforms

When a waveform is recorded with the block average option active, additional information is available to assess repeatability of the response. Clicking on **[Averaging > Block Averaging Phasor Display]** will show a polar plot for the selected waveform. The plot is located below the EEG side panel, which will open automatically when the option is activated. The information displayed on the plot is based on the currently selected analysis frequency and block size selected from the other options in the **[Averaging]** menu.

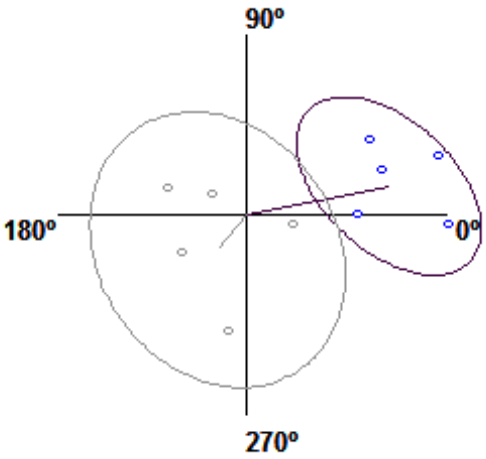


Figure 23 - Block Average Analysis

The recording shown in Figure 23 is the analysis corresponding to a waveform with 5 blocks. The violet elliptical area, to the right of the graph, shows the general area for the phase of the response in the individual blocks. The actual phase of each block is represented by the small blue circles. The average phase of the entire average (all blocks together) is represented by the line of the same color, the length of this line is also indicative of the response amplitude.

The grey elliptical area, encompassing the center of the graph, shows the general area for the phase of the noise in the individual blocks. The phase of the noise of each block is represented by the small grey circles. The average phase of noise in the entire average is represented by the line of the same color, the length of this line is also indicative of the noise amplitude.

Note that in the example, the phase of the response in the blocks is a narrow area when compared to the noise; this is an indicator of a repeatable response at the given analysis frequency. It also is confined to a smaller angular region in the polar plot, where the noise area encompasses most of the angular regions in the plot; this is also an indicator of repeatability. In the example, the length of the line for the response is longer than the line corresponding to the noise.

Special Case: the cochlear microphonic

The Split-Sweep waveform plot type can be used to view the effects of the cochlear microphonic. In this case the goal is to observe a repeatable structure, found in the first milliseconds of acquisition in the ABR response, which is inverted when changing the polarity of the stimulus. To see it, the recording must have been acquired using the Alternating polarity, so that the waveform contains the average of the rarefaction sweeps in one recording and the average of the condensation sweeps in the other. When changing the Plot Type to Split-Sweep, the cochlear microphonic should be easy to identify.

Alternatively, it is possible to view the microphonic by acquiring separate condensation and rarefaction averages, then super-imposing the waveforms.

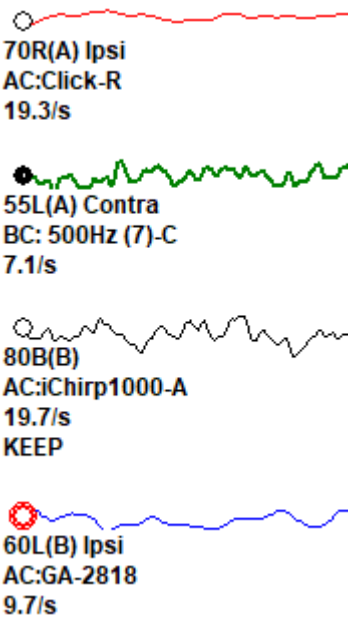
Data Processing and Analysis

8

Waveform Identification

There are multiple ways to recognize the modality and parameters that were used to acquire a recording, including the text indicators at the start of the plot and the color of the plotted waveform.

The indicators at the start of the waveform include multiple data markers. The stimulus information and acquisition rate can be shown or hidden using the options in the main menu under **[Show > Show Recording Label]**. The first line, includes the following information:



- The intensity of the stimulus in dbs. The number will show the nominal value whether the stimulus was presented in HL or SPL.
- The channel of acquisition in parenthesis; this is also indicated by the color of the plot, typically red for right, blue for left and black for both. Note that the selected waveform will always be a green plot.
- The mode of acquisition, whether it was ipsilateral (Ipsi) or contralateral (Contra). When acquiring from both sides, there will be no indicator, as shown in the third waveform on the right.

The second line of text, the stimulus information will include the following:

- If the stimulation was delivered via air conduction (AC) or bone conduction (BC). If you wish to see the stimulator choice, right click on the waveform, and look at the recording information option.
- The stimulus type, whether it is click, a generated frequency or the name of a loaded STM file.
- When using a generated tone burst (second waveform in the example) the envelope used will be indicated in parenthesis. In case example above, the 500Hz tone was presented using envelope code 7, or Blackman.
- The polarity of presentation, where the options are rarefaction (R), condensation (C), and alternating (A). For waveforms acquired using the Advanced Auditory modality (fourth waveform in the examples) the polarity of each component is shown after the stimulus name. Each digit corresponds to each component's polarity matching the order on the setup window, where 0 is alternating, 1 is rarefaction, 2 is condensation, and 8 means the stimulus component is OFF,

The third line shows the rate of acquisition. If the waveform is tagged as KEEP, using the right-click context menu, the marker will appear as the last line, as shown in the third waveform above.

Any additional information about the waveform acquisition and stimulation settings can be obtained by using the recording information panel located on the right-hand side of the screen. If the panel is not open, click on the **[Rec Info]** button to make it available. Additionally, right-clicking on the waveform will open the context menu, with all the data listed on the file name and information item at the top of the menu.

Placing labels

Labels are very important tools as they will help you determine the latencies and amplitudes of the expected response. Each label consists of two markers, a top arrow pointing down, and a bottom triangle pointing up. The top marker helps determine the latency at which a peak or valley occurs, where the bottom marker helps determine the amplitude of the waveform by calculating the difference in voltage between the top and bottom marker. Placed labels are saved to the recording then the recording is saved, or a report is saved. Marker labels can be placed on a recording in two ways:

- Using the marker buttons on the toolbar. First select the recording that you wish to label, the markers shown may update to reflect the selected recording type. Click on the label button (on the toolbar) once, notice that the selected label marker will be highlighted in red; then click just above or below the location where you want the label's top marker to be placed.
- With the recording selected, right click at the location where you want the label's top marker to be placed. From the context menu, select either **[Mark Peak]** and the standard label you wish to place, or **[Mark Other Peak]** to select from non-standard labels. Once the label is in place, left-click-hold and drag the bottom marker to its proper location.

When printing marked recordings, applicable labels to the type of recording will be listed on a table at the bottom half of the printed page. The Table will also include any meaningful calculations such as SP/AP ratios or the inter-peak latencies in ABR recordings. If the table information for a specific recording is not showing, the recording may have been acquired using the wrong modality. To correct this, simply re-save the recording using the **[Data > Save File As]** option from the SmartEP main menu.

If labels are not being placed, it is likely that you are attempting to place a new label too close to an existing one. To achieve closer placement of labels, first place it further away, then drag or move it into place.

Moving Labels

Once placed, the label markers can be moved in two different ways:

- Click on the marker that needs to be moved, and while holding the left mouse button, drag it into position. This can be used to move any top or bottom label marker.
- Click on the label to select it, the label pair will be colored red to indicate that it is active. Once the label is active, use the following arrow key combinations to move the markers:
  - **[←]** or **[<]**: Moves the top marker, for the selected peak label, earlier on the time scale.
  - **[Shift]** + **[←]**: moves the top marker by a larger amount.
  - **[Alt]** + **[←]**: moves the bottom marker.
  - **[Shift]** + **[Alt]** + **[←]**: moves the bottom marker by a larger amount.
  - **[→]** or **[>]**: Moves the top marker, for the selected peak label, later on the time scale.
  - **[Shift]** + **[→]**: moves the top marker by a larger amount.
  - **[Alt]** + **[→]**: moves the bottom marker.
  - **[Shift]** + **[Alt]** + **[→]**: moves the bottom marker by a larger amount.

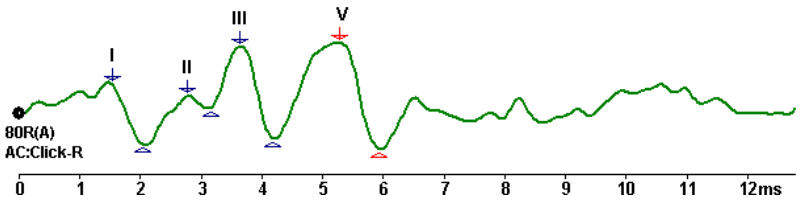


Figure 24 – Sample waveform with peak V selected

ECochG markers

There are three main markers used for identifying ECochG recordings.

- SP: Summating Potential.
- AP: Action Potential.
- Base.

All these are usually located in the 0.5 to 3 ms range. The relative relation between these three, allow the calculation of SP/AP ratios. After placing the labels on the recording, move the bottom Base marker across the waveform while keeping it at the same level (Base amplitude should be 0), then move the bottom markers for SP and AP to the same location. If the area calculation is not shown, turn it on by right clicking on the waveform and choosing **[ECochG Area Measurement]**. You may also choose **[Mark Other peak]** then activate it using the check box next to the ECochG labels, then click **[Apply to All]** if it should be set for all ECochG waveforms.. The setting is also available from the [Rec Info] panel, in the Display tab. Note that some users may prefer to see an inverted waveform to the one shown below. A CM marker is also available from the toolbar.

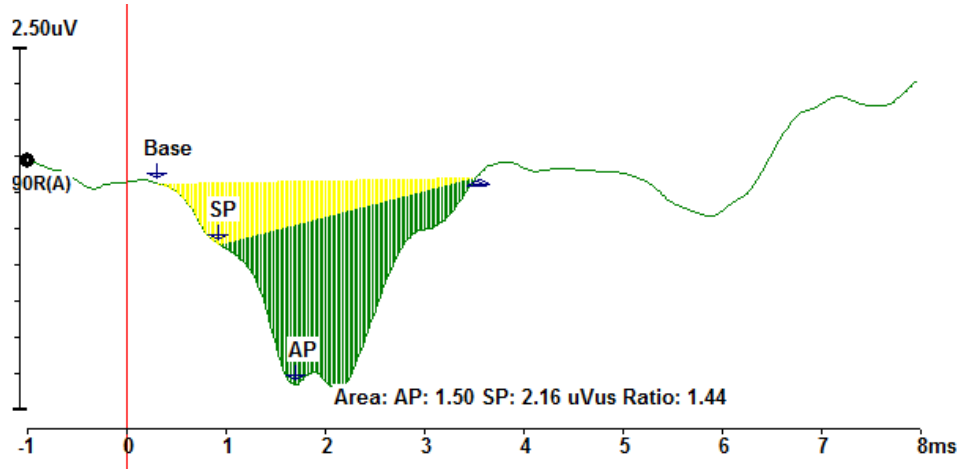


Figure 25 - ECochG recording with peak labels and area calculation

ABR markers

Peaks I, II, III, IV, V, VI, and VII are used to identify the structure of the auditory brainstem responses. All of these features are usually located in the 1 to 15 millisecond range. Make sure to move the bottom markers to the correct location so that the software can calculate the Peak Amplitude values. When marking peaks, I, III, and V the inter-peak latencies will be calculated automatically and then added to the printed data table and recording information panel.

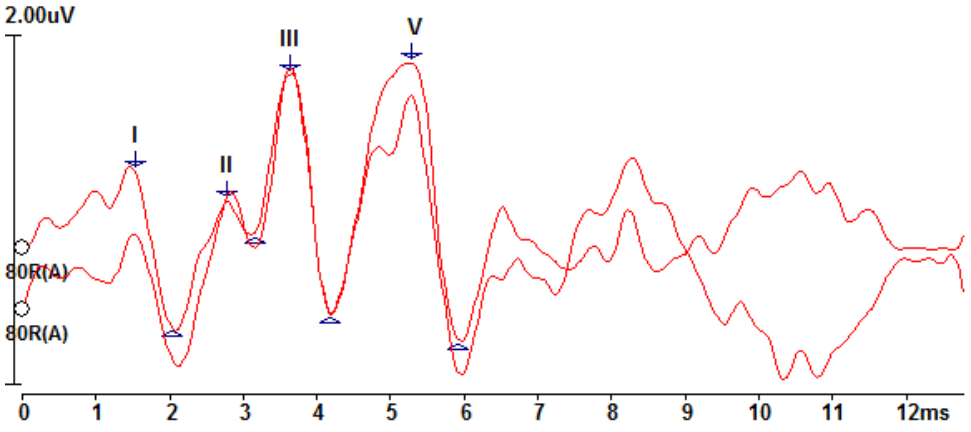


Figure 26 - ABR waveform with peak labels.

MLR markers

The labels No, Po, Na, Pa, Nb, and Pb are used to mark the structure of a middle latency response. All of these are usually located in the 12 to 50 millisecond range. Make sure to move the bottom markers to the correct location so that the software can calculate the Peak Amplitude values.

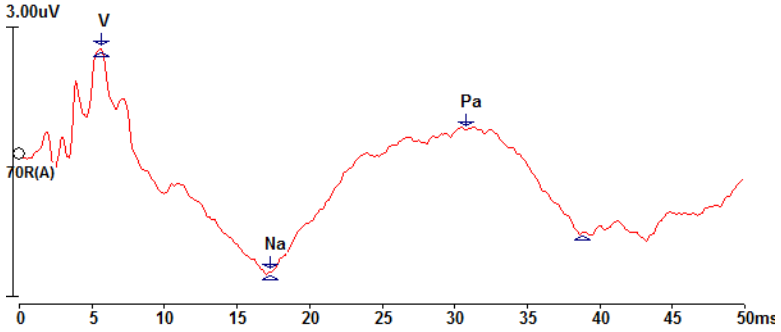


Figure 27 - MLR waveform with peak labels

LLR markers

The labels P1, N1, P2, N2, P50, N50, P75, N75, P100, N100, N145, and P175 are used to mark late latency responses. All of these are usually located in the 50 to 250 millisecond range. Make sure to move the bottom markers to the correct location so that the software can calculate the Peak Amplitude values.

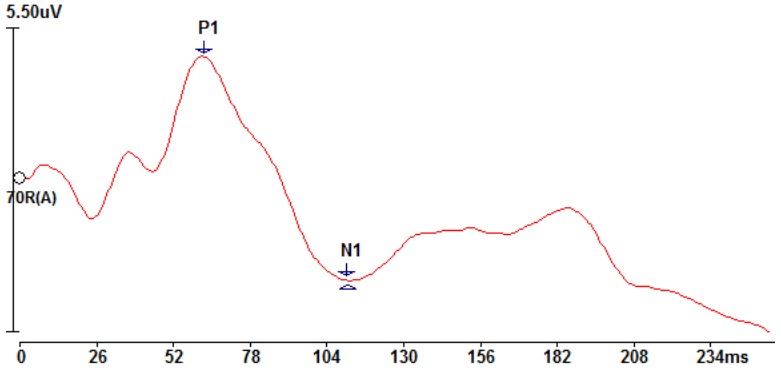


Figure 28 - LLR waveform with peak labels

P300 markers

P3, N3, P300, N300. All of these are usually located in the 250 to 350 millisecond range. Make sure to move the bottom markers to the correct location so that the software can calculate the Peak Amplitude values. See P300 labeling on page 87 for additional details.

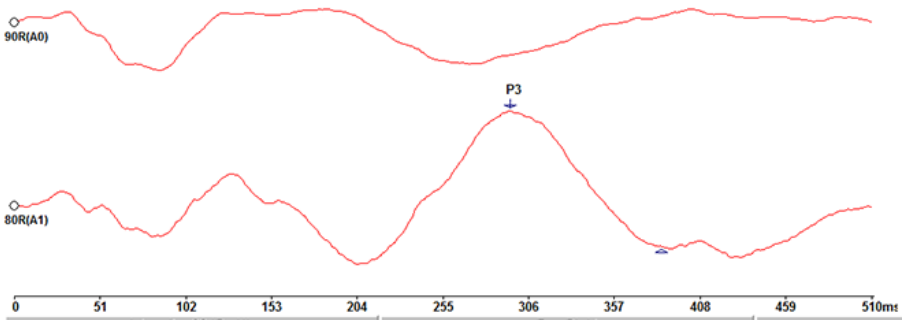


Figure 29 - P300 waveform with peak labels

MMN markers

MMN. Usually located in the 100 to 300 millisecond range. The bottom marker of the MMN recording will define the zone for which the Area of the curve is calculated. The part of the curve used for the calculation will be shown in yellow. Make sure the top and bottom markers for the MMN label are within the same half cycle or the calculation cannot be completed. See MMN labeling and area calculation on page 88 for additional details.

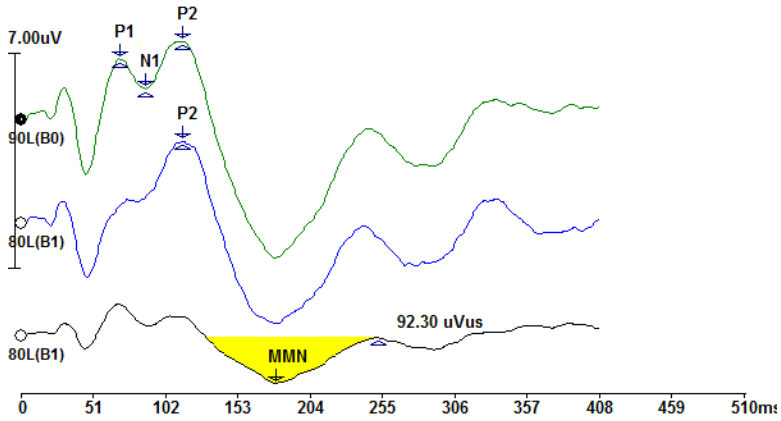


Figure 30 - MMN waveform and labels

Other markers

Additional markers, such as those for Visual Evoked Potentials (VEP), Somatosensory Evoked Potentials (SSEP), and Pattern electroretinography (PERG) are available on the Peak Labels window. The window can be accessed by right clicking on a waveform and choosing 'Mark other peak'. Details about these label markers can be found in their respective sections of this manual, or in a separate manual in the case of PERG.

User defined labels

Users can define specific labels to be used to mark their recordings. User Defined labels are saved with the file as soon as they are placed, so even if they are moved and loaded into a different computer, the label will remain.

Creating a label

1. Right click on a recording to open the Peak Labels window.
2. In the 'User Defined Labels' field, enter the text for your label.
3. Click on the **[Add to List]** button.
4. Click on the **[Save List]** button.

The label list can also be modified directly by editing a text file. This should only be done by users who are familiar with the Windows operating system. The list can be found in the 'Settings_EP' folder in the "UserPeakLabels.Txt" file. This file can be edited directly by entering one label name per line using any text editor, like Windows Notepad. Note that a custom label may be placed without saving the list first, this will place and save the label on the recording, but the label will not be available from the list in the future.

Placing a user label

1. With the recording selected, right click over the position where you want the label placed.
2. From the context menu, select **[Mark Other Peak]**.
3. Choose the label you want to place from the list of 'User Labels'.
4. Click on the **[Mark Peak]** button.

Latency and intensity values of placed labels

The values for latency and intensity of placed labels can be found at multiple locations.

- At the bottom of the printed report page or PDF document, if active.
- In the 'Peaks' tab of the Rec Info panel. The panel may be opened by pressing the **[Rec Info]** button at the right side of the screen.
- Right next to the label when the feature is active, from either the **[Show]** menu, or from the 'Display' tab in the Rec Info panel.

Showing latency and amplitude information next to labels

There are multiple options for showing the latency and amplitude information directly in the page. Note that the amplitude information will not be shown until the bottom marker is moved.

- To show information for a single waveform: Click to select the waveform, then from the 'Display' tab in the 'Rec Info' panel, choose "Show text - next to label". You may also activate it from the main menu by picking **[Show > Show Text Next to Peak Label > Apply to Selected Data]**
- To show information for all waveforms on the page: From the main menu, click on **[Show > Show Text Next to Peak Label > Apply to All Data on Page]**
- To show information automatically for future recordings (not yet acquired): From the main menu, activate the option found as **[Show > Show Text Next to Peak Label > Apply to Acquired Data]**. When this option is checked, all newly acquired recordings will automatically show the latency and amplitude information when a new label is placed.

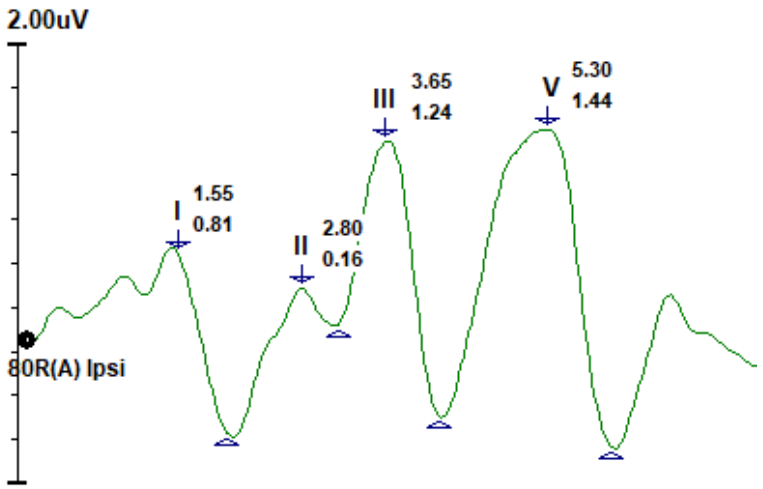


Figure 31 - Recording with peak labels showing latency (above) and amplitude (below) next to each label

Post-acquisition filtering

Once a recording has been acquired it can be filtered with either a smoothing filter, or spectral filters as needed. Filtering post acquisition is a non-destructive process since the original data will be preserved in the original recorded file. When filtering a waveform, it is copied to a new recording, leaving the original recording intact. Note that if you want to keep this filtered version, you will need to save the recording manually, or save a report.

Smoothing filter

The smoothing filter in SmartEP is a Finite Impulse Response Filter. Settings allow for smoothing from very mild (7-point smoothing) to very strong smoothing (25-point smoothing). To smooth a recording:

1. Click on **[Process > Filter > Filter Type]** from the SmartEP main menu.
2. In the window that opens, select the **[Filter Type]** as 'FIR', and adjust the slider to the left for less filtering, or to the right for more filtering.
3. Click **[OK]** button to close and confirm your selection.

When filtering only one response, select the recording to filter, then click on the filter button from the toolbar (button shown on the right) or click on **[Process > Filter > Active Recording]** from the main menu. When filtering all the recordings in the current page, click on **[Process > Filter > ALL on Page]** instead.

Spectral filter

The digital spectral filters in SmartEP have two possible options. The Band Pass filter keeps frequencies from the high pass value to the low pass value, frequencies falling above the low pass or below the high pass will be filtered out. Band Pass filtering is typically used to filter out strong high frequency or low frequency noise, where the noise falls outside the selected filter settings.

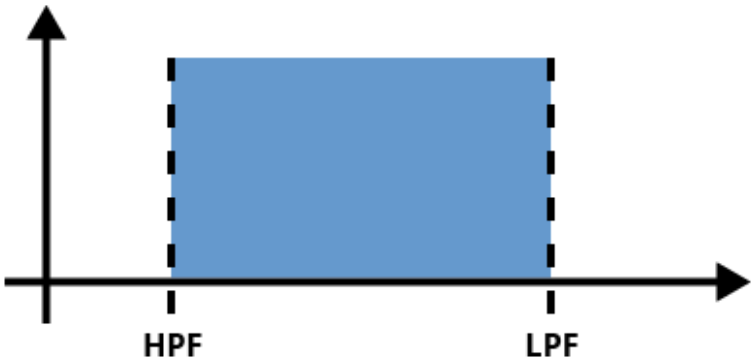


Figure 32 - Digital band pass filter, frequencies not contained in the range are filtered out.

The Notch option filters out the frequencies in between the selected low pass and the high pass filters, leaving intact those that fall outside the range. The Notch option can be used when the line noise was too high and shows up in the response, filtering out the power line frequency (50 or 60 Hz, depending on location) while leaving the rest of the response untouched.

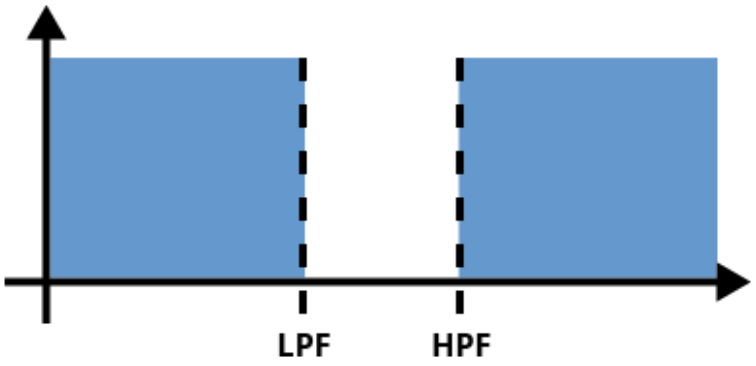


Figure 33 - Digital notched filter, frequencies inside the range are filtered out.

To filter a recording using a digital spectral filter:

1. Click on **[Process > Filter > Filter Type]** from the SmartEP main menu.
2. In the window that opens, choose whether you want to use a 'Band Pass filter' or a 'Notch filter'.
3. Enter values for the low and high pass filters.
4. Click **[OK]** button to close and confirm your filter selection.

When filtering only one response, select the recording to filter, then click on the filter button from the toolbar (button shown on the right) or click on **[Process > Filter > Active Recording]** from the main menu. When filtering all the recordings in the current page, click on **[Process > Filter > ALL on Page]** instead.

Calculating alternate averages (block)

When the waveform has been acquired while the block average feature is enabled, it is possible to change the averaging method using some of the options in the main menu. Using different methods may lead to improved, more recognizable, or repeatable responses. To change the averaging method for one recording, simply select the waveform, and then choose one of the "Calculate - Averaging" options from the **[Averaging]** menu. To change the averaging method for all recordings on the page, choose one of the "Calculate - Averaging All on Page" options from the menu. Waveforms acquired as blocks will be marked as 'wBLOCKS' on the data file list. The following methods of averaging are available:

- **Standard Averaging**: This is the default averaging technique that is commonly used to acquire evoked potential data. It involves adding all corresponding data samples obtained at a specific time position and dividing the sum by the number of measurements or sweeps. The Standard Average represents the simple average of all values acquired at the data point. Artifact rejection is used to exclude sweep samples that are determined to be out of the range selected by the user.
- **Weighted Averaging**: For each sweep block, a variance and residual noise measurement is determined. The variance and measurement will indicate how much the data has fluctuated from is mean value and the residual noise measurement will indicate how similar or different the sweeps are from each other. Larger fluctuations and difference between sweeps are typically associated with more EMG activity and noise. A weighting factor is calculated for each sweep based on the reciprocal factor of the variance and residual noise. The weighting factor is applied to all data points for the sweep before adding together the corresponding time values to calculate the average response.
- **Median Averaging**: For each corresponding data time point, all the individual measurements for each sweep are sorted and the median value determined. The median value is the number that divides the higher half of the data samples from the lower half. For example, if at a specific data time point the following set of 7 samples are collected: {120, 410, 231, 489, 212, 321, 340}, the sorted array would be {120, 212, 231, 321, 349, 410, 489}. The median value would be 321. Median Averaging will eliminate the effect of high or low spurious data on the resulting median average.
- **Smart Averaging**: Smart Averaging uses the same weighting scheme as Weighted Averaging, but also incorporates additional block-by-block filtering based on the user designated Smart Averaging Filter settings and block averaging rejection. Blocks containing residual noise measures of 3 µV or greater will be automatically excluded from the average. This is in addition to sweeps previously rejected based on the standard artifact rejection level selected by the user. The 3 µV criteria was selected based on typical residual noise levels obtained for blocks of 10 sweeps recorded under various levels of active EMG conditions in order to optimize response quality. The criterion is currently not adjusted for the selected block sweep count. Increasing the base block sweep count will automatically decrease the measured residual noise range, reducing or eliminating the blocks rejected.

In each of these cases, the new average will include data from all blocks, it only shifts the contribution of each block to be relative to the quality of the data based on the selected option.

Grand Averages and Adding waveforms

Two or more waveforms can be added up to create a new averaged waveform. There are two methods of addition 'Sweep Weighted' and 'Microvolt Weighted'.

- A **Sweep Weighted** addition will take in consideration the number of sweeps that each added recording contains, creating a grand average; In this case, adding two similar acquired recordings with 1000 sweeps each would be the equivalent of just acquiring a single one with 2000 sweeps.
- A **Microvolt Weighted** addition will result in a direct sum of the waveforms, instead of an average.

To choose which method to use, select the option by clicking on the **[Process > Addition/Subtraction Mode]** option from the SmartEP main menu. To add two waveforms:

1. Select the addition mode from the main menu.
2. Activate one recording by clicking on it, or it's handle. The handle of the currently selected recording will turn to a black filled circle, and the waveform will change color to green.
3. Activate the other recordings to be added by clicking on them while holding the **[Ctrl]** key on the keyboard. Any other recordings selected will have a grey handle.
4. Select **[Process > Add Selected Recordings]** the to add them or press on the **[+]** key on the keyboard. A new recording will appear with the resulting waveform.
5. If there are many recordings that need to be acquired, it may be easier to load them all to a single page and then use the **[Process > Add all on Page]** menu item. Waveforms that are the result of an addition operation will be assigned a higher value line thickness for ease of identification.

Aligning peak V

Some procedures may require you to add ABR recordings by aligning peak V. Instead of adding the recordings based on the existing timeline, adding with a peak V aligned will time shift the recorded data in order to match the pre-marked Peak V labels. Keep in mind that in order for this operation to be successful, all recordings must have their peak V labels in the correct place before activating this option. Most commonly, a microvolt weighted addition is used for these cases. There are two ways to make this calculation:

- **Add All on Page (Peak V Aligned**): will add the recordings and time shift the recordings to match the earliest occurring peak V.
- **Add All on Page (Peak V Aligned - Mean Latency)**: will add the recordings and calculate the mean latency of Peak V for the recordings being added. After addition, it will time-shift the result to make the new Peak V match the calculated mean latency.

Additional operations

Subtraction

Two recordings can be subtracted in an operation resulting in Recording A minus Recording B, Where A is the active recording (in green with the black handle), and B is the secondary recording (standard recording color and gray handle):

1. Select operand B from the recordings on your screen by simply clicking on it, or it's handle.
2. Hold down the **[Ctrl]** key on your keyboard and select operand A by clicking on it, or it's handle.
3. From the main menu, choose **[Process > Subtract Two Selected Recordings]**, or press the **[-]** key on your keyboard.
4. A new recording will appear with the resulting operation. Make sure to save it if needed.

Inversion

Sometimes it may be necessary to invert a recording, simply because the electrodes were accidentally reversed, or maybe a subtraction operation was performed while selecting the recordings in the wrong order.

1. Select the recording to invert by clicking on it, or it's handle.
2. From the main menu, choose **[Process > Invert Active Recording]**.
3. To save the recording with this new polarity, click on **[Recordings > Save Active Recording]**, or click the **[Save EP File]** button in the toolbar.

Time-shifting

Recordings can be shifted in time to account for unforeseen delays, to account for stimulus delays, or to align one recording with another.

1. Select the recording to time-shift by clicking on it, or it's handle.
2. From the main menu, choose **[Process > Time Shift Active Recording]**.
3. Enter the time-shift value in milliseconds. Use positive numbers to shift data to the right, and negative numbers to shift data to the left.
4. The time-shifted recording will be placed in a new average. To save this data, click on **[Recordings > Save Active Recording]**, or click the **[Save EP File]** button in the toolbar.

Splitting the recording

Each recording contains two internal averages. When data is acquired, the even numbered recordings get averaged together, while the odd numbered ones get averaged into second internal average. For example, when acquiring an ABR in alternating polarity, all the rarefaction sweeps will be placed in one recording, while the condensation will be placed in the other. To separate them

1. Select the recording by clicking on it, or its handle.
2. From the main menu, choose **[Process > Split Active Recording]**.
3. The two internal averages will be split into two new recordings. To save these, click on **[Recordings > Save Active Recording]**, or click the **[Save EP File]** button in the toolbar.

Waveform comparisons and norms

Waveform comparisons may be necessary to determine the reliability of a response, to compare results of one subject against the general population, or to evaluate results from one side to another.

ABR latency-intensity comparison

To view a latency-intensity graph and table of the marked ABR recordings, click on **[Show > Show Latency-Intensity graph]**, or click on the Latency Intensity Graph button from the toolbar. This will open a window showing the marked peaks in a Latency vs. Intensity graphic, and an accompanying data table. Normative data will be displayed as a gray shaded area of the graph, while the marked data on the page will be a red or blue line across the graph. Specific data can be shown/hidden using the channel and stimulation side controls at the top right of the window.

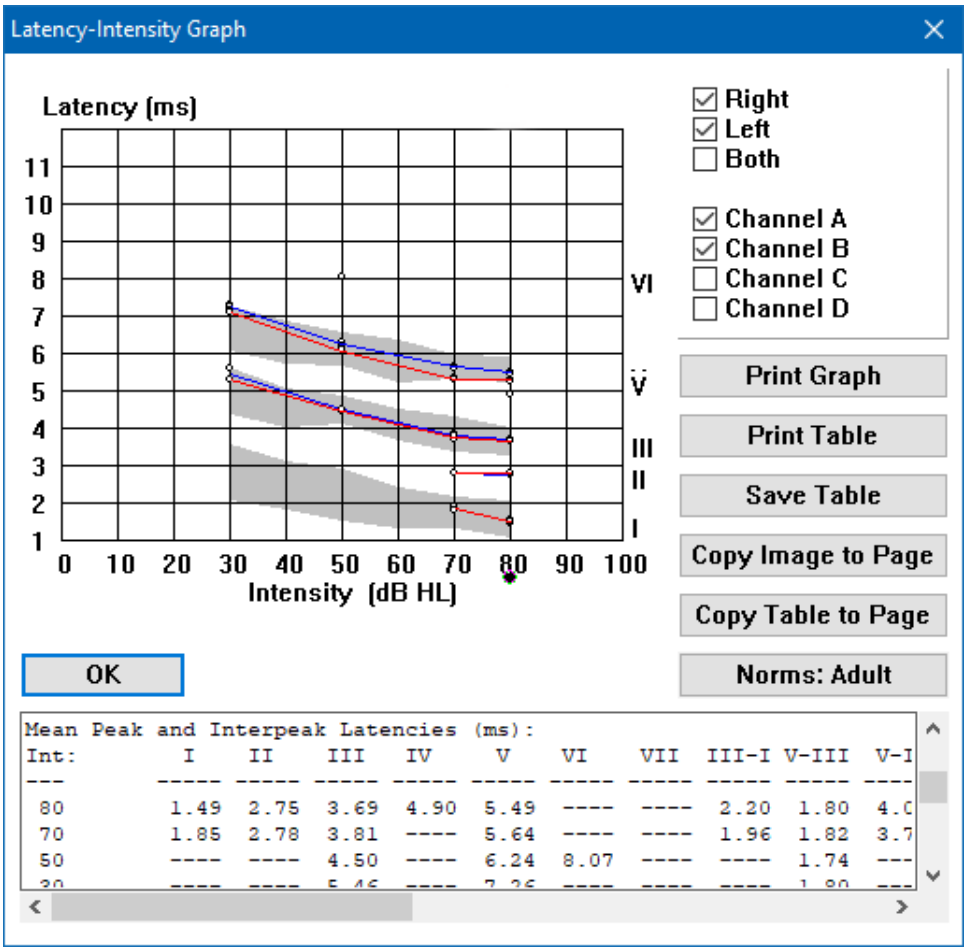


Figure 34 - Latency-Intensity window

If normative data is not showing, it is because no normative data has been saved as default. To fix this, refer to Default normative data on page 15. it is also possible to load a custom normative data set; to use a special normative data file, which has been previously created, simply click on the **[Norms]** button and select the desired file.

The red or blue lines correspond to right and left ears, respectively. If they are not showing on the graph, then the responses have not been marked correctly, or the correct side-channel combination is not active. Make sure the waveforms are defined ABR recordings (the 4th letter on the file name will be an 'A'). Also make sure the channel and stimulus side selections boxes, at the top right of the window, match the data that needs plotting.

Cross-correlating two recordings

This function will help determine how similar two recordings are. For the purpose of this calculation, an area of comparison needs to be pre-defined; the cross-correlation value will be calculated for the portions of the recordings falling within this area. The resulting number is a fractional number where 1 is perfect correlation, the larger the difference between the two recordings, the lower the value will be.

1. Turn on Cursors to be able to define the cross-correlation area. Click on **[Show > Show Cursors]** to turn them ON. When ON, the option has a check mark to the left of it.
2. Move the cursors to the start and end points of your cross-correlation region. Cursors can be moved by dragging on the handle and the bottom of each cursor. When turned ON, cursor handles can be found at the bottom left of the recording area, just above the time scale.
3. Select the two recordings while holding the **[Ctrl]** key.
4. From the main menu, click on **[Process > Cross Correlate > Two Selected Recordings]**.

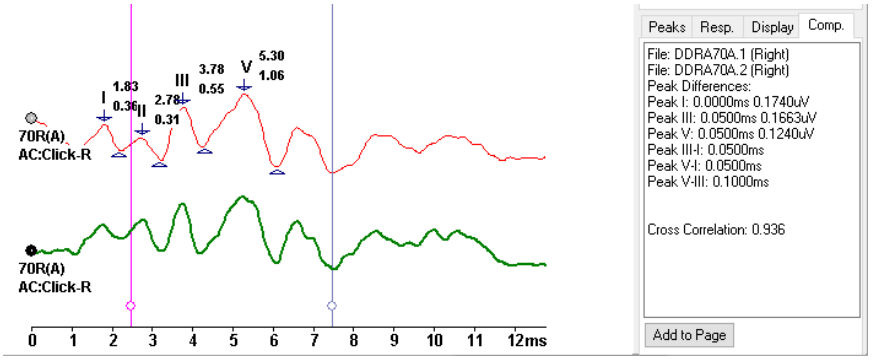


Figure 35 - Cross Correlation of two waveforms

Self-cross-correlation

Since each recording contains two internal averages, these can be compared to each other to judge the repeatability of the waveform. To see the cross-correlation in the same region as the SNR calculation region, simply click on the **[Rec Info]** button and look at the Response panel, the last field will show the corresponding cross-correlation value. To choose a different area:

1. Turn ON Cursors to be able to define the cross-correlation area. Click on **[Show > Show Cursors]** to turn them ON. When ON, the option has a check mark to the left of it. You may also toggle them by clicking on the Show Cursors button in the toolbar.
2. Move the cursors to the start and end points of your cross-correlation region. Cursors can be moved by dragging on the handle and the bottom of each cursor. When initially turned ON, cursor handles can be found at the bottom left of the recording area, just above the time scale.
3. Select the recording by clicking on it, or its handle.
4. From the main menu, click on **[Process > Cross Correlate > Within Active Recording]**.

Note: to graphically view the contents of both internal averages (on a single recording), right click on the recording and select **[Plot Type > Split Sweep]**, to return it to normal view select **[Plot type > Average]**.

Cross-correlating to all others on page

1. Turn ON Cursors to be able to define the cross-correlation area. Click on **[Show > Show Cursors]** to turn them ON. When ON, the option has a check mark to the left of it. You may also toggle them by clicking on the Show Cursors button in the toolbar.
2. Move the cursors to the start and end points of your cross-correlation region. Cursors can be moved by dragging on the handle and the bottom of each cursor. When initially turned ON, cursor handles can be found at the bottom left of the recording area, just above the time scale.
3. Select the recording by clicking on it, or its handle.

4. From the main menu, click on **[Process > Cross Correlate > Active Recording with All on Page]**.
5. A Notepad file will open with the cross-correlation values when the selected recording is compared to all the ones currently in the page.

Comparing recordings from opposite sides.

In some instances, it is necessary to compare a recording acquired from the left channel to one acquired from the right channels. Before doing this, make sure the recordings you want to compare have been acquired using the exact same parameters or the comparison will not work. The resulting comparison data will depend on the type of data being compared.

1. Mark all necessary labels on the recordings being compared.
2. Select both waveforms by holding the **[Ctrl]** key and clicking on them, or their handles.
3. From the main menu, select **[Process > Compare Two Selected Recordings]**.

If all the comparison parameters are valid, then a pop-up window will show the results of the comparison. These results can be placed on the page as well.

Comparison information can also be obtained by opening the recording info panel and selecting the two recordings. The comparison information will be displayed in the 'Comp' tab. It can also be added to the page directly from there.

Waveform power spectrum

Some advanced users, mainly researchers, may want to look at the frequency components of the waveforms recorded. There are multiple ways to see this information.

Displaying a recording in spectral mode

To see the recording directly in spectral mode, right click on it to open the context menu, then select **[Plot Type > Spectral]**. The recording will now be shown as two graphs. The color waveform (green if selected) shows the spectral plot of the average from both internal averages (A+B), while the black waveform shows the spectral plot of the difference between the averages (A-B). Notice that while this recording is selected, the 'Time' display in the indicator line will change from showing time position to showing frequency position.

Viewing a detailed spectral graph

To view a more detailed power spectrum of the recording, select the recording, then click on **[Process > Spectral Analysis > Active Recording]** from the SmartEP main menu. The Spectrum Analysis window will open showing the full recording including the pre-stimulus area on the left, and the power spectrum of the recording on the right. The post-stimulus region is shown in Blue, while the pre-stimulus region is shown in Red. It is possible to adjust the spectral graph using the sliders at the bottom right corner of the window. The graph can also be shown as a dB plot, the current graph can be printed, or it can be saved to an ASCII file and imported into a third-party program. Note that when using the **[Process > Spectral Analysis > All on Page]** option from the SmartEP main menu, the power spectrum data will be saved to an ASCII file, not displayed on the screen.

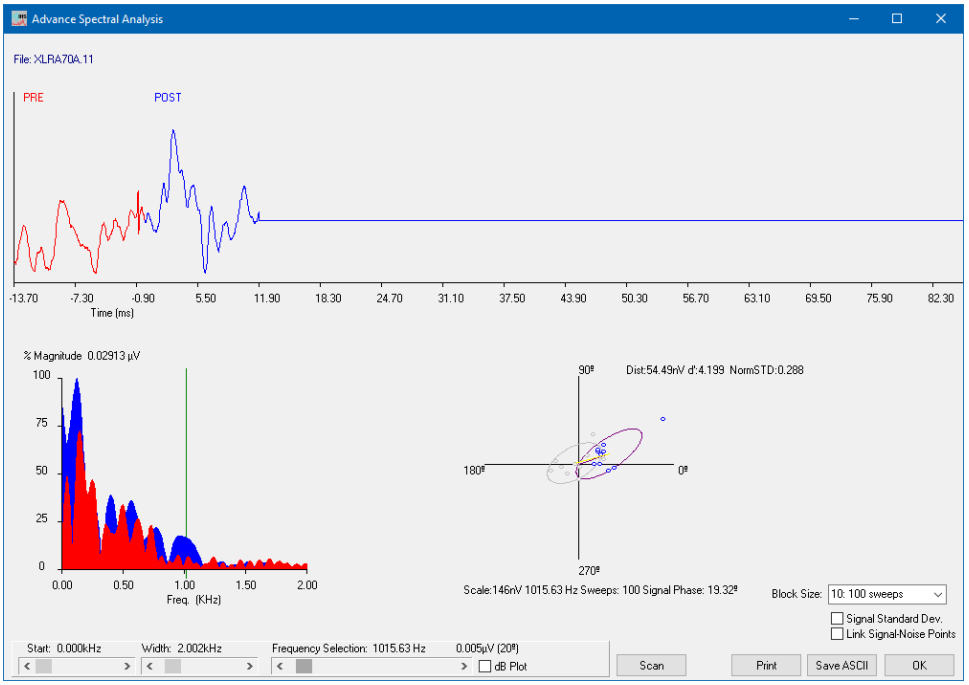


Figure 36 - Spectral Analysis window showing an ABR recording

Phasor Analysis for block averages:

The SmartEP system provides a phasor analysis of AEP recordings acquired in the Block Averaging Mode. This mode allows the recorded data sweeps to be stored in small blocks that can be re-averaged using different techniques and allow statistical analysis to be conducted. The block size can be selected by the user from the Averaging menu. When the Block Averaging Phasor Display option is enabled, the phasor diagram for the selected recording will be displayed on the lower portion of the right-side panel as shown in Figure 37.

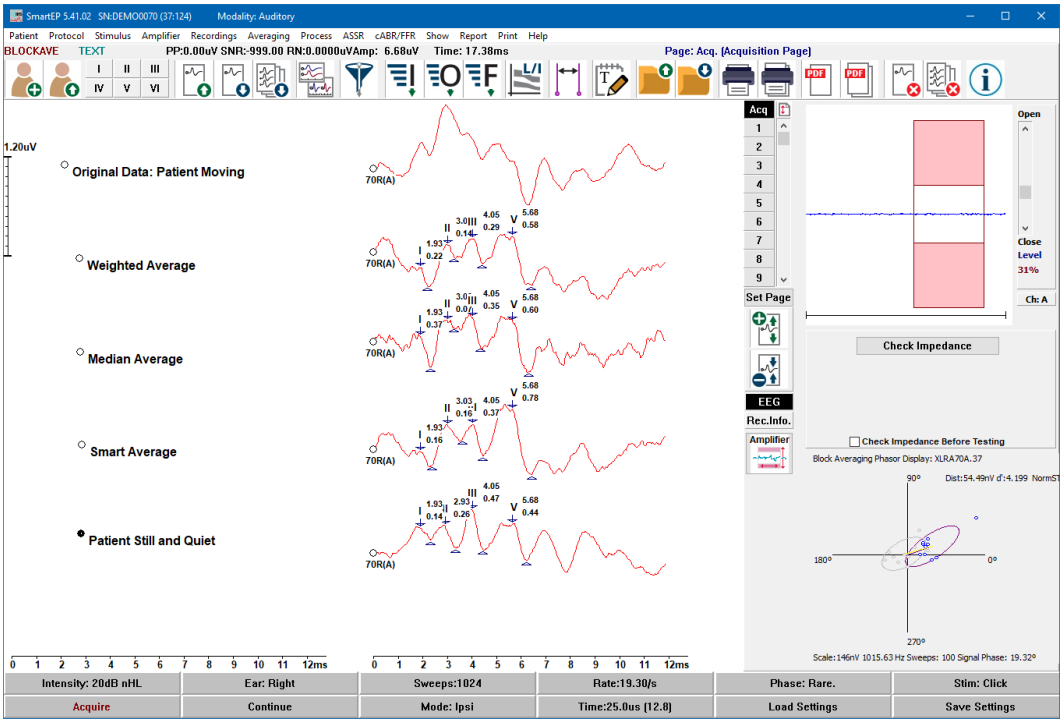


Figure 37 - SmartEP Main window showing multiple recordings and Block Averaging Phasor display at bottom right

Understanding the Block Averaging Phasor Display

The Phasor display provides important information pertaining to distribution of the signal and noise estimates for each recorded sweep block.

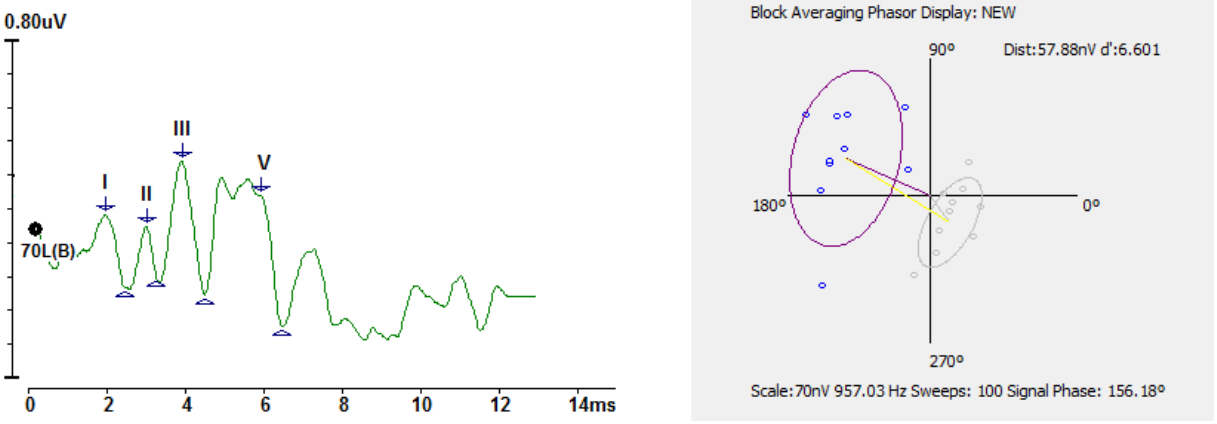


Figure 38 - Block averaged acquired recording and corresponding phasor display.

The display, shown in Fig. 63, indicates the response file name (next to the display header), the plot scale (in nV), analysis frequency, number of sweeps per block and signal phase (along the bottom of the display) , the "distance" (Dist:) between the center of the signal and noise estimate distributions in nV and its corresponding

d' value. The d' value, also referred to as the sensitivity index, is a dimensionless statistical measure of the distance or separation between the two distributions in mean (signal and noise) standard deviations. The individual block signal estimates are represented by small blue circles with a purple vector to the center of the distribution and a larger purple ellipsoid representing the 95% confidence interval of the signal estimates. The individual block noise estimates are represented by small gray circles with a gray vector to the center of the noise distribution and a larger gray ellipsoid also representing the 95% confidence interval of the noise estimates. The yellow line linking the mean signal estimate (purple vector) and the mean noise estimate (gray vector) indicates the distance between the two distributions.

The Phasor may be evaluated at various frequencies (analysis frequency). In the case of Auditory Brainstem Responses, the primary frequencies containing the response energy are at approximately 200, 500 and 900 Hz. These frequencies correspond to the temporal relationship between the various response peaks that are generated after auditory stimulation. The analysis frequencies may be scanned to determine the optimal response frequency for any recording using the **[Scan]** button in the Advanced Spectral Analysis display (see "Additional Display Options" later in this section).

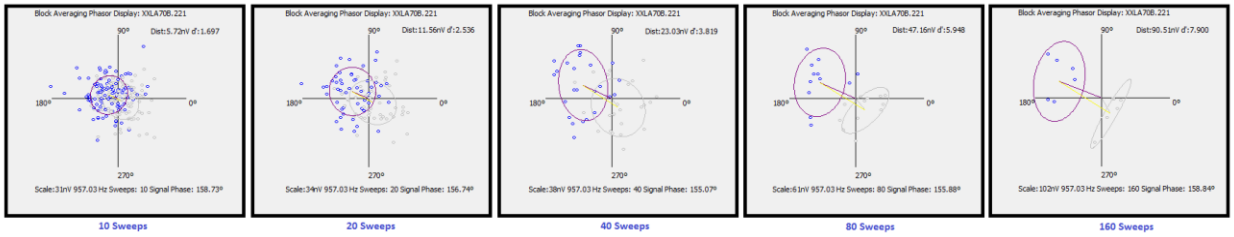


Figure 39 - Phasor diagram for the same recording while choosing different block sweep sizes

The sweep size of the blocks will determine how much response signal energy can be determined for each block. As shown in Fig. 64, when the sweep block size is small, there is very little difference between the noise and signal estimates (Fig. 64, First Panel). As the number of sweeps contained in each block increases, the signal and noise estimate separate indicating the presence or absence of a response.

Additional Display Options

From the Advanced Spectral Analysis display (accessed by selecting the **[Spectral Analysis]** option in the Process Menu), additional display options for the Block Averaging Phasor Display may be selected. These include linking corresponding signal and noise estimate points (gray lines connecting signal and noise estimates) and Standard Deviation display for the signal (green concentric lines indicating 1-3 standard deviations from mean signal estimate).

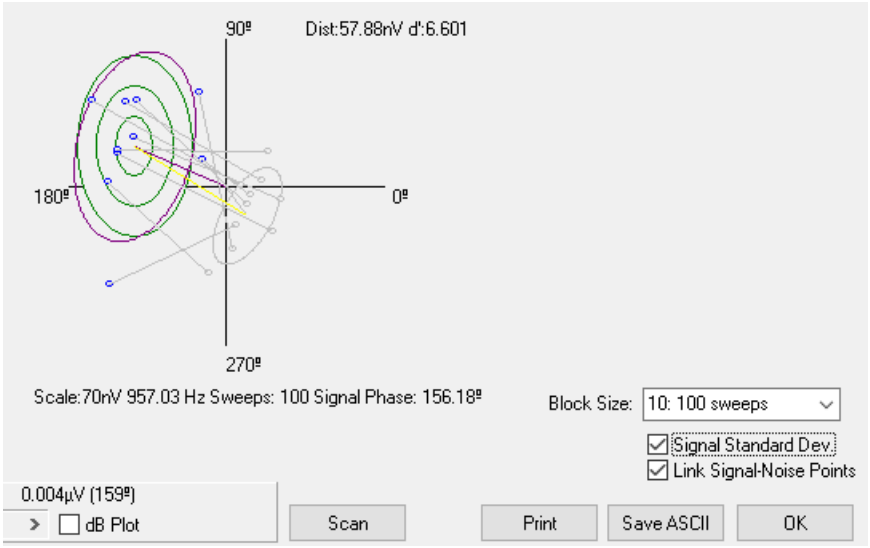


Figure 40 - Linked signal and noise data points and standard deviation

Fsp and Fmp Objective Measures

The Single-Point F-ratio (Fsp) and Multiple-Point F-ratio (Fmp), are objective measurements for evaluating the presence of a response based on the variance of a single point or multiple points, respectively. Fsp and Fmp values for the current response can be seen in the Response Tab of the Recording Information Panel, and on the recording information section of the recording right-click menu. The Fmp value can also be found to the right of the RN value in the indicator bar.

To obtain Fsp and Fmp measurements, the Block averaging option must be active (see Block Acquisition and Averaging on page 45). When acquiring different types of evoked potentials, it may be beneficial to move the Fsp point to a location in the time scale where the response is expected to be strongest. The Fsp point can be selected by clicking on **[Averaging > Fsp Point]** then choosing one of the options:

- Choose **[Select Fsp point]** to enter a value manually
- Choose **[Select Fsp point from Active Cursor]** to have the software extract the position of the active cursor (pink) in the time scale.

The Fsp and Fmp values will be calculated based on the selected Fsp point before acquisition. The Fmp points are adjusted automatically when defining the Fsp point, where it uses 10 points to either side of the Fsp point on the time scale. After acquisition, you may choose a different Fsp point, then recalculate using **[Averaging > Fsp Point > Update Active Fsp/Fmp Value]** from the main menu.

The progress of the Fsp and Fmp values can be obtained by choosing to display progress in block steps, choose **[Averaging > Fsp Point > Update Fsp/Fmp Value and Display Progress]**; this will load new cumulative block averages to the screen, and will open a table data in Notepad showing the progression of the values as more blocks were obtained. The step size (number of blocks per step) of this feature is defined in the **[Averaging > Block Averaging Analysis Block Size]** option in the main menu.

Managing Recordings

9

Saving and renaming files

In SmartEP recordings are saved automatically as they are completed. Recordings will need to be re-saved after labeling and after post-acquisition processing has taken place, and the data was placed in a new recording, such as when adding, subtracting, or splitting a recording. Unsaved files will show the name as 'NEW' in the indicator bar.

Saving an individual file

These two steps will save one single recording, assigning a file name automatically based on the standard SmartEP naming convention.

- Select the recording you wish to save by clicking on it, or its handle.
- From the SmartEP main menu click on **[Recordings > Save Active Recording]** or click on the 'Save EP File' button in the toolbar.

Saving all displayed files

This will save all the file currently on the screen. Recordings that are labeled as 'NEW' will have file names automatically assigned based on the standard SmartEP naming convention. To do this:

- Click on **[Recordings > Save All Recordings]** from the SmartEP main menu or click the '**Save All EP Files**' button in the toolbar.
- This can also be accomplished by saving a report using **[Report > Save Report]** from the main menu, or the button of the same name in the toolbar.

Saving as a different data type

If a recording was acquired under the wrong modality, it may be assigned an incorrect data type. This situation may prevent proper labeling and the automatic calculation of some ratios. To recognize a recording acquired under the wrong modality, look at the fourth letter in the recording name, which indicates modality and refer to the "Naming convention" section that follows. To correct this issue:

1. Select the recording with the incorrect data type by clicking on it, or its handle.
2. From the SmartEP main menu, click on **[Recordings > Save Active Recording As…]** and choose the correct data type from the submenu.
3. The recording name will change to reflect the new data type.

Custom file names

It is possible to fully customize the name of a recording using the **[Recordings > Save Active Recording As… > Specific File Name]** option in the main menu. Any name could be used; however, it is better to adhere to the naming convention so that SmartEP can properly recognize the data type and perform any required automatic calculations.

Naming convention

File names in SmartEP are of the following format: 'xxSMiiC.nn'. Where:

- xx: Patient's code. This code is based on day and number of patients for that day.
- S: Side of stimulation. R for right, L for left, B for both.
- M: Testing modality. E for ECochG, A for ABR, M for MLR, L for LLR, P for P300, V for Visual, R for P50, and T for Somatosensory.
- ii: Intensity value. This indicates the intensity value that was used, be it SPL or HL.
- C: Hardware acquisition channel.
- nn: Recording Number. Numbers are used incrementally when more than one recording shares the same settings as specified in the rest of the file name.

The same naming convention applies to other IHS programs; some of these have different indicators for modality including D for ASSR and O for TEOAE.

Loading Recordings

To load previously acquired recordings, individually or in groups:

1. Make sure you have the correct patient file loaded.
2. Click on **[Recordings > Load Recordings]** from the main menu or click on the Load EP File button from the toolbar.
3. If you are searching for a specific recording type, select it from **[Recording Type]** check boxes and deselect the ones you do not need. This should help you narrow the list in patients where many different tests have been run.
4. Use the sorting options if needed by clicking on the **[Sort Order]** radio buttons.
5. Select the recording you wish to load by clicking on it on the list, the selected recording will have a blue background. To select consecutive recordings, hold the **[Shift]** key on your keyboard while clicking on the first and the last recordings you want to load. To choose more than one recording, not shown consecutively, hold down on the **[Ctrl]** key while clicking on the items from the list.
6. If you want to pre-select how the recordings are arranged on the page when loaded, click on the desired option at the bottom right of the window. Choose between 'Intensity', 'Acquisition Order', 'Stimulation Rate', or 'None.'
7. Click **[OK]** to load.

Moving recordings into report pages

When acquiring multiple consecutive sets of data, it is best to separate the data using the 10 possible display pages. This can be used to separate data when performing a threshold search at multiple frequencies, where the data from each stimulus frequency will be separated by page. It is also useful when running multiple protocols such as ECochG, ABR, and P300 on the same patient. Some of this can be accomplished automatically as described in Organizing and tagging recordings on page 77. To manually move recordings, do one of the following:

- A single recording can be moved by:
  - Selecting the recording, right-clicking on it, then choosing one of the options in the **[Send to Page]** submenu.
  - Selecting the recording, then dragging it using the mouse (holding the left mouse button and moving it) to one of the page buttons on the right-hand side of the screen. This method can also be used to separate data on a split-page mode between the right and left sides of the page.
- Multiple recordings can be moved by:
  - From the **[Set Page]** buttons select one of the options under **[Send All Data on this page to]**. Keep in mind that this option will move all data on the page to the chosen destination.

- Hold the **[Ctrl]** key and select multiple recordings; then while still holding the **[Ctrl]** key, hold the left mouse button and drag them to the page number on the right-hand side of the screen.

When placing recordings on a page, the button on the side menu corresponding to that page will be shaded a different color than an empty page, this is an indicator that there is data in that page.

Showing recording information

Recording information can be shown directly on the report page by modifying settings found in the **[Show]** menu, and in the Rec Info panel.

Showing peak label latency and amplitude on the page

The peak latency and amplitude will appear at in the table at the bottom of the printed report pages, you may also see this information by scrolling down the page on the screen. The peak information may also be shown directly on the waveform by using the option outlined in Latency and intensity values of placed labels on page 60.

Showing acquisition parameters on the page

Some of the acquisition parameters can be display at the start of each tracing:

- Stimulus Information: From the SmartEP main menu, click on **[Show > Show Recording Label > Stimulus Information]**. This information will be shown below the stimulus delivery type (such as AC for air conduction and BC for bone conduction), followed by the stimulus type (such as Click or specific frequency), and the phase of the stimulus (A for alternating, C for condensation, and R for rarefaction).
- Rate of Acquisition: From the SmartEP main menu, click on **[Show > Show Recording Label > Rate Information]**.

Note that these settings apply to all waveforms on the page.

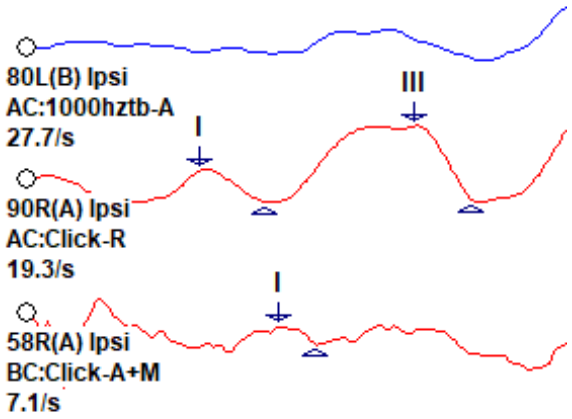


Figure 41 - Stimulus and Rate information displayed at start of recording.

Renaming Report Pages

Of the 10 different pages in SmartEP, pages 1 thru 9 may be renamed to more accurately reflect their contents and to help with data organization. To rename a page, right-click on it, or click on **[Set Page]** button, then click on the **[Page Label]** option. Two prompts will ask first for the shown button label (up to 4 characters long), and then for the page name, which will appear when the mouse is over the button, as well as at the top left of the report page when printed. The Acquisition page, labeled **[Acq.]**, may not be renamed.

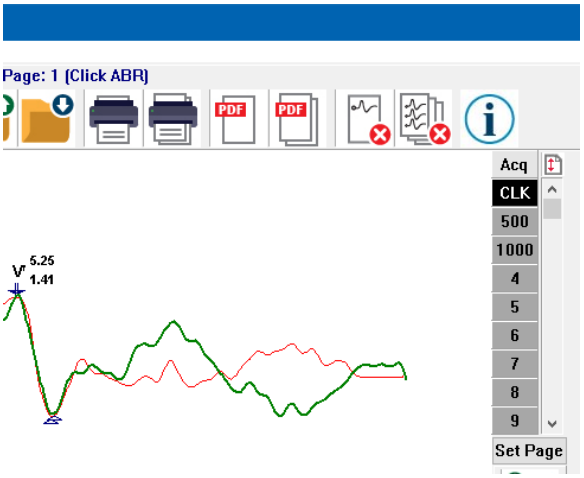


Figure 42 - Page labels changed for pages 1-3

In Figure 42, the example shows Page 1 has been renamed to “CLK”, Page 2 has been renamed to “500”, and page 3 has been renamed to 1000; the printed pages however will carry a label of “Click ABR”, “500 Hz Tones”, and “1000 Hz Tones” respectively.

Saving and Loading Page Labels and Attributes

The setup of page labels and the page attributes, including scale, plot size, and other page parameters settings may be saved, loaded, and saved as default using the options in the **[Set Page]** menu. The page labels files have a “.PLS” extension and must reside inside the “**Settings_EP**” folder.

When using Page Labels and Attributes, keep in mind the following:

- The Page labels and Attributes may be saved as default by choosing that option from the **[Set Page]** menu. This will create a file called “DEFAULT.PLS”. This file will load every time SmartEP is opened. To restore the original factory page defaults, load the file “SmartEPIHSPageDefaults.PLS”, then re-save your default file.
- When saving a report, the page labels and attributes will be saved with the report.
- When loading a previously saved report or auto-report, the page labels and attributes from the report will load as well and will override the current page labels and attributes.
- When loading PLS files while data is present, or a report has been opened, the loaded labels and attributes will override the current labels and attributes. Any waveforms already present will be re-scaled to match the newly loaded attributes.
- The page settings, such as time and amplitude scale on the Acquisition page are modified when loading a PLS file. They can be changed back by reloading the .SET settings file used during acquisition, or by changing the acquisition modality.

Organizing and tagging recordings

Features accessible from the **[Show]** menu and in the toolbar can help keep the page organized and help make the recordings easier to identify. The software can arrange the recordings automatically as they are acquired, when loaded, or after acquisition is completed. The recordings can be automatically arranged by intensity, by acquisition rate, or by acquisition order.

- While Acquiring: in the SmartEP main menu, choose the desired arrange method from the options given under **[Show > Acquisition Auto-Arrange by]**. Recordings will be organized according to the specified setting as soon as they are finished acquiring.
- While Loading: in the Load Data window, select one of the arrange options from the panel at the bottom right of the window.
- After Acquisition: Select one of the show options from the **[Show]** menu. Available options include "by Intensity", "by Acquisition Order", and "by Frequency". Equivalent options can be found in the toolbar, marked as "I", "O", and "F" respectively. In addition, pressing the keyboard keys **[I]**, **[O]**, or **[F]** will also rearrange the waveforms, respectively.

Changing the page display settings

Generally, data is shown on the screen in a normalized vertical scale with a horizontal time scale corresponding to the type of testing being performed. In certain cases, it may be necessary to change these settings to better accommodate the data, or to make it easier to analyze. All options for changing the way that data is shown can be found in the side menu, which can be opened by clicking on the **[Set Page]** button. None of these options make any changes to the actual acquired data, just to the way it is shown.

Scale and Scaling

Scale refers to the vertical unit of measurement used for showing the recordings. Usually, the scale is set to normalized page mode by default. The vertical scale indicator may be moved around the page using the top handle. The following modes are available:

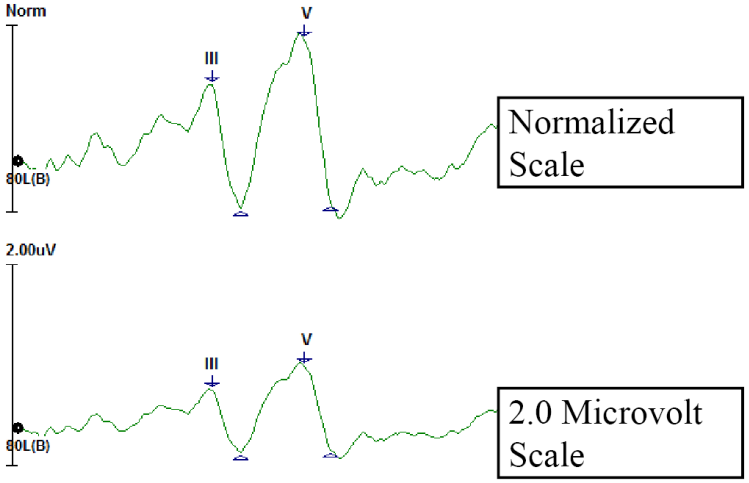


Figure 43 - Same recording shown in different scales.

- **Normalized**: The software looks at each individual recording, detecting its maximum and minimum values and "zooming" in-on it, making it fit on the allotted space (defined by the 'Plot Size' setting in the **[Set Page]** menu). This setting is useful when looking for thresholds to low intensity stimuli; however, the expected decrease in amplitude based on response to the stimulus level will not be observed.
- **Normalized Page**: The software looks for the recording with the largest Peak-to-Peak amplitude and sets the vertical scale based on that recording; all others on the page will be also set to that vertical scale.

This setting is useful to observe the decrease in response amplitude as stimulus level decreases. This is the optimal setting for report generation.

- **Microvolt Values**: A user can set a specific vertical scale value by choosing one of the pre-set values or entering a custom one. This setting is recommended when there is a need for consistency from one report to the next, or when trying to provide additional zoom to a particular area of interest. Keep in mind that setting too small a value, one that exceeds the peak-to-peak amplitude of the recordings on the page, will lead to clipping as seen on Fig. 68.

Creating advanced reports

Most users will only organize recordings, mark the corresponding peaks, and then print a results sheet. Advanced users may want to create more complete reports including additional text and comment fields, tables with data across pages, or data acquired in other IHS programs. The following items can be added to any SmartEP report page.

- Recordings from SmartEP-ASSR and SmartTrOAE can be loaded directly using the **[Recordings > Load Recordings]** menu option.
- Single lines of text can be added using the **[Report > Add > Label]** menu option.
- Paragraphs, or text fields with multiple lines can be added using the **[Report > Add > Text]**. Additional options include adding text pre-populated with recording or demographic information. Options labeled as 'Static' do not change when the source changes, options labeled as 'Dynamic' will change when the source information changes.
- All static text fields, including demographics information, data tables, and recording information can be edited manually by right clicking on the report item while it's selected and choosing the **[Edit]** option from the context menu.
- The recording information table, normally shown at the bottom of the printed page, can also be added to the page, then moved to a different page, if needed.
- New items are always added to the top-left of the screen, keeping this area clear while building the report might help with selecting and moving items around the page.

Saving and loading reports

Once all data is acquired, and any additional report items are created and organized, the report can be saved to a file using one of the following options:

- Click on **[Report > Save Report]** from the main menu.
- Click on the **[Save Report]** button on the toolbar.

The saved report file is simply a collection of pointers to the individual file and report items on the page. Keep in mind that permanently deleting, or moving, a data recording, or a report item, from the drive will make it impossible for a report to load that recording and will prompt with an error indicating that the data is not found. If this happens, re-save the report so that it will not give an error next time it is loaded.

To load a previously saved report, use one of the following options:

- Click on **[Report > Load Report]** from the main menu.
- Click on the **[Load Report]** button on the toolbar.

Reports can also be saved to a PDF file, keeping an electronic copy of it.

Data export tools

Exporting one or more recordings to ASCII

The point-by-point information contained in the recording can be exported to a text file, also known as ASCII files. These types of files can be easily imported into spreadsheet application or many other applications. To export a single recording, select it by clicking on it, then select **[Recordings > Save As ASCII... > Active]** from the main menu. To export all recordings on the page, select **[Recordings > Save As ASCII... > All on Page]**. The ASCII file contains the following information:

- Recording information including:
  - Patient identifier (see Patient File Management on page 18 for more information).
  - Recording file name (see Naming convention on page 74 for naming details).
  - Ear of stimulation, Marked as Left (L), Right (R), or Both (B).
  - Channels used for acquisition, 1 for channel A, 2 for channel B, etc.
  - Stimulation rate in presentations per second.
  - Stimulus mode (sound output channel), There are 4 internally defined channels of sound output, shown here in binary ON (1)/OFF (0) coded as '(R1)(R2)(R3)(R4)'. A code of '1' means only the first right channel was used, A code of '101' means that the first right channel and the first left were used.
  - Number of averaged sweeps.
  - Number of artifacts.
  - Sampling period, length of time between samples.
  - Amplifier gain.
  - Low pass filter.
  - High pass filter.
  - Notch filter status as TRUE when it's ON or FALSE when it's OFF.
  - Stimulus type code, '1' for clicks, '100' for tones, or the actual file name when using a pre-defined stimulus file.
  - Stimulus frequency, if using tones.
  - Stimulus duration in milliseconds.
  - Masking level in dB SPL.
  - Zero-time position in points (time of stimulation).
- Table of peak information including:
  - Label: label name.
  - Peak (+): top peak marker data point position.
  - Peak (+) (ms): top peak marker equivalent time position.
  - Peak (-): bottom peak marker data point position.
  - Peak (-) (ms): bottom peak marker equivalent time position.
- Data point information table including:
  - Data Pnt: Data point number. Each recording will have 1024.
  - Data Pnt (ms): Data point time position in milliseconds.
  - Average: 16-bit A/D value. If multiple data files are being exported, there will be one column per data file.
  - Average: average amplitude value converted to microvolts. If multiple data files are being exported, there will be one column per data file.
  - Buffer1 and Buffer2: 16-bit A/D values for each internal average. This information is only included when exporting a single data file.
  - Buffer1 (µV) and Buffer2 (µV): average amplitude values converted to microvolts. This information is only included when exporting a single data file.

Exporting the FFT to ASCII

The FFT of a recording can be exported using the options in the Advanced Spectral Analysis window. The resulting text file will contain most of the same information as the exporting of Time data except for the microvolt values for each of the internal averages and the recording grand average. Instead, it will include the following fields:

- Frequency: The frequency of the plot point.
- Pre-Spectra (pV^2): Value of power at the frequency for the pre-stimulus region.
- Pre-Spectra(dB): Value of power at the frequency in decibels for the pre-stimulus region.
- Pre-Phase(Deg.): Phase of the response at that frequency for the pre-stimulus region.
- Post-Spectra (pV^2): Value of power at the frequency for the post-stimulus region.
- Post-Spectra(dB): Value of power at the frequency in decibels for the post-stimulus region.
- Post-Phase(Deg.): Phase of the response at that frequency for the post-stimulus region.

Printing

Printing records

The contents of the report pages can be printed to the default windows printer using one of the following options:

- Use the **[Print > Print Page]** menu item to print the report page currently displayed.
- Use the **[Print > Print ALL Pages]** menu item to print all report pages containing information. Blank report pages will not print when using this option.
- Click on the respective **[Print]** buttons, **[Print Page]** or **[Print All Pages]**, from the toolbar to print a single page or all report pages.

Note that although the vertical scale may have been moved to a different location on the report pages, it will always print at its original location, at the top-left.

Enhancing printing quality

Some printers may print the waveforms too light, such as when printing waveforms of certain colors to a black and white printer. There are a couple of settings in the **[Print]** menu to help improve the printing quality:

- Activate the Black and White setting from **[Print > Black & White]** in the main menu, this will print all waveforms as if they were black, making them a little darker on the printed page.
- Change the line thickness of the printed waveforms by choosing a higher number from **[Print > Line Thickness]**. This will modify the thickness of the printed waveform, while keeping the waveform display on the screen the same.

Printing to electronic file (PDF)

SmartEP can generate an electronic copy of the report without the need for a printer. To create the PDF format file:

- Use the **[Print > Print Page PDF preview]** menu item to print the report page currently displayed.
- Use the **[Print > Print All Pages PDF Preview]** menu item to print all report pages containing information. Blank report pages will not print when using this option.
- Click on the respective **[Print]** buttons from the toolbar to print a single page or all report pages.

Note that although SmartEP can generate the PDF format files, the computer still needs to have a PDF viewing application installed in order to open the files. A free PDF reading application may be obtained directly from Adobe Systems at the following location: https://get.adobe.com/reader/

P300 and MMN Modality

10

Suggested electrode placement

The same electrode setup can be used for P300 and MMN protocols. When using less acquisition channels than your unit is capable of handling, short out the unused channels by connecting a Y-adapter between the corresponding Red (-) and Blue (+) sockets. Any type of surface electrodes should work well for this type of acquisition.

Dual channel setup for Duet

This is the recommended electrode setup when using the Duet hardware platform.

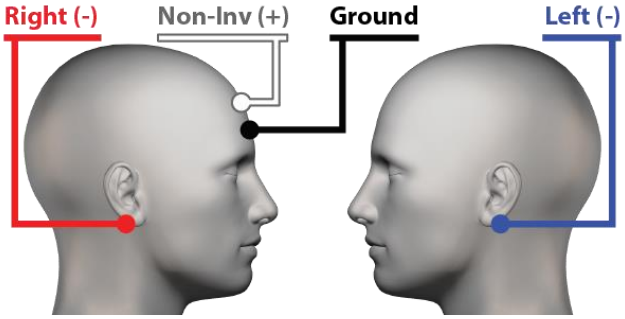


Figure 44 - Electrode placement for P300 on Duet

- Red (-): snap or socket connected to the right mastoid (M2) or earlobe (A2).
- Blue (-): snap or socket connected to the left mastoid (M1) or earlobe (A1).
- White (+): snap connected to high forehead. (Fpz). If using the 5 Electrode Leads cable, join the White and Grey sockets together using a Y-adapter.
- Black (⏚): snap or socket connected to mid or low forehead (below Fpz).

Linked ear lobes are also a commonly used setup for the inverting electrodes. For this option, the 5 Electrode Leads Patient Cable must be used in combination with a linked electrode adaptor (reverse of Y-Adapter).

Single Channel setup for Duet

To use the Duet for single channel acquisition, the 5 Electrode Leads Patient Cable must be used in combination with a Y-Adapter.

- **Inverting (-)**: ipsilateral mastoid using the red or blue electrode lead; (right or left setup, respectively).
- **Non-Inverting (+)**: to the forehead using the White or Grey lead; (right or left setup, respectively).
- **Ground (⏚)**: Black lead connected to the contralateral mastoid.
- **Unused (-) and (+)**: Join the unused positions together using the Y-Adapter; either Red and White together when using a left ear setup, or Blue and Grey together when using a right ear setup. Merged end is left unconnected.

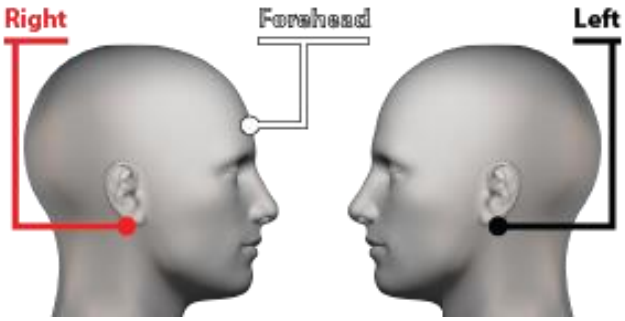


Figure 45 - P300 using a single channel, right ear setup

Dual channel setup for USB and USB Jr.

When using a transmitter with two or more channels, use the following setup. If switching the stimulation from one ear to the other simply click on the **[Ear]** button from the control panel.

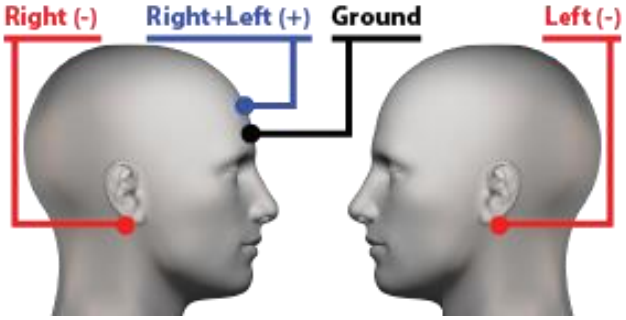


Figure 46 - Electrode placement for dual-channel setup

- **Red (-) Channel A**: socket connected to right mastoid (M2) or earlobe (A2).
- **Red (-) Channel B**: socket connected to left mastoid (M1) or earlobe (A1).
- **Blue (+) Channel A and B**: sockets joined together using a Y-adapter, connected to the high forehead. (Fpz)
- **Black (⏚)**: socket connected to mid or low forehead (below Fpz).

Linked ear lobes are also a commonly used setup for the inverting electrodes. If the amplifier has more than two channels, the unused channels should have their inverting (Red) and non-inverting (Blue) positions joined by Y-Adapters to short-out the channels; merged end of Y-Adapter is left disconnected.

Single channel setup for USB and USB Jr.

If using a single channel transmitter, simply set the test **[Ear]** in the control panel, and the use the toggle switch on the transmitter itself to match. The selected ear's electrode will become inverting (-), the opposite ear will become the ground (⏚), Black is always the non-inverting (+) electrode.

Using a single channel Opti-amp

- **Red**: connected to the right mastoid.
- **Black (+)**: connected to the high forehead (Fpz).
- **Blue**: connected to the left mastoid.

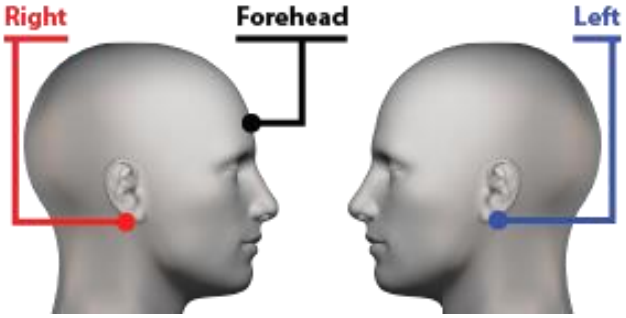


Figure 47 - Electrode placement using a single-channel transmitter

Using one channel on a multi-channel Opti-amp

- **Inverting Electrode (-)**: Connected to the ipsilateral mastoid (left mastoid M1 or right mastoid M2). Red socket of channel being used.
- **Non-inverting Electrode (+)**: to the high forehead (Fpz). Corresponding Blue socket for the channel being used.
- **Ground (⏚)**: to the contralateral mastoid. Black socket.

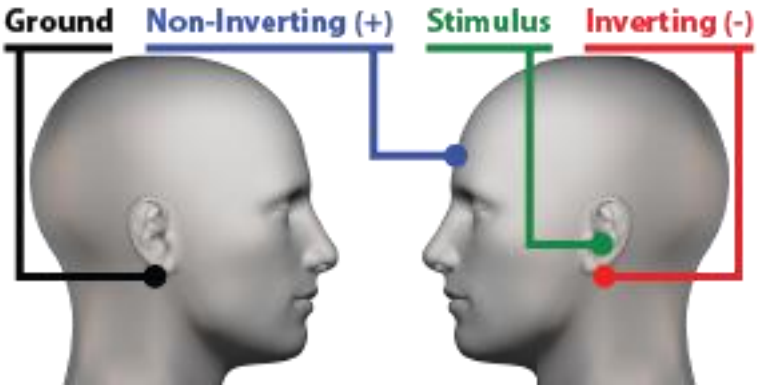


Figure 48 - Electrode placement using a dual or multi-channel transmitter with left-ear stimulation

When using a multi-channel transmitter with this setup, make sure to change the channel designation In the Amplifier window to match the stimulation side, or to the 'ON' setting. Multichannel transmitters should have their unused channels shorted, by using a Y-adapter connected between the inverting (Red) and non-inverting (Blue) sockets of the same channel for better results; merged end can be left unconnected.

Blink rejection electrodes

For P300, eye blink rejection electrodes will help you discard sweeps during which the patient blinked. Rejecting these sweeps can sometimes make the difference when trying to obtain good, repeatable recordings. You can choose to use an EyeBlink amplifier on a USB Box or use one of your unused acquisition channels for this function.

The EyeBlink amplifier for the USB Box

The EyeBlink Amplifier is an optional component, available only for the USB Box, used for rejecting averages based on user-defined EEG level criteria. When using this accessory, it is possible to reject sweeps when the patient blinked, otherwise the muscular action of the blink (artifact) may end up being averaged into the response; sometimes modifying the average greatly.

The same result can be achieved using standard acquisition channels; however, adding an EyeBlink channel is more economical than adding a full acquisition channel to a USB unit. This item is only available for the Universal Smart Box and goes connected to it using its own Fischer connector. When the P300/MMN module is active, the Eye-Blink channel (Channel I) will become active, but only work if you have the EyeBlink hardware connected.

For the Duet

Note that this can only be done when setting up a single acquisition channel, and by using the 5 Electrode Leads Patient Cable.

1. Place the unused channel's inverting electrode above the center of the eyebrow (Blue socket on a right ear setup. Red socket on a left ear setup), on either the left or right eye.
2. Place the unused channel's non-inverting (Grey on a right ear setup, White on a left ear setup) electrode on the upper cheek, just below the bottom eyelid, on the same side as the electrode placed in step 1.

For the USB Box and USB Jr.

Note that if using a USB Jr., you are limited to one acquisition channel as the second channel will be used for eye-blink rejection.

1. Place the Red electrode above the center of the eyebrow, on either the left or right eye.
2. Place the Blue electrode on the upper cheek, just below the bottom eyelid, on the same side as the red electrode.
3. If using an EyeBlink Amplifier, place the Black ground electrode on the shoulder blade, or any other convenient location away from the other two electrodes. If using a standard acquisition channel, the ground will be shared with all other channels.
4. If using an EyeBlink amplifier, turn the amplifier 'ON' using the switch at the front of it. If using a standard acquisition channel, set that channel's designation to 'ON' in the Amplifier Settings window.
5. Measure impedances by pressing the two impedance checking buttons, or using the corresponding rotary switch positions, at the front of the amplifier.
6. If using an amplifier with a rotary switch, do not forget to set it to the ON position before continuing.

Setting up the blink rejection region

1. If not already active, activate the P300/MMN modality by choosing **[Protocol > Modality > Auditory P300/MMN > P300]** from the main menu.
2. Click on the **[Amplifier]** button to the right side of the screen to open the EEG window.
3. In the channel selection area of the window, notice the Channel I - Eye-Blink channel active. Select that channel by clicking on its radio button if using an EyeBlink Amplifier; otherwise select the standard channel you chose to use for this purpose, and make sure its designation is set to 'ON'.

Notice the "Level" slider may be set all the way to 100%, meaning it is accepting all sweeps. Ask the patient to blink repeatedly so you can see the effects on the EEG, then reduce the level by moving the slider down until it looks like all blinks will be rejected (when the EEG artifacts are touching the pink region), while keeping the non-artifacting EEG from hitting the rejection area.

Patient state

P300

When performing a P300 protocol, the patient MUST remain alert. The patient should be instructed to pay attention to the deviant stimuli and keep track of it. Most recommendations include having the patient count the number of deviant stimuli, and although the actual number is not important, it can help the operator judge whether the patient paid attention or lost interest in the middle of the procedure.

Giving the patient something to do when they hear the deviant stimulus can also help keep them alert. This can include a small push-button for patients to press or having them lightly tap on their foot. Keep any activity to the minimal possible muscle movement to avoid the muscle activity from showing up on the recordings as added noise. Advise the patient to not close their eyes while the procedure is running, as this can lead to the patient falling asleep or stop paying attention.

It also helps to keep the sweep count small, acquiring multiple smaller averages and engaging the patient in conversation between one acquisition and the next. The smaller averages can be added together into a grand average later, post-acquisition (see Grand Averages and Adding waveforms on page 64).

MMN

In contrast, when performing an MMN protocol, the patient does not need to be alert. Simply a relaxed state, even sleep is valid for MMN acquisition.

Settings for acquisition

The following are generic suggested settings, but they may be modified as needed to fit your protocol or to match existing literature.

P300 settings

Before changing any settings make sure the P300/MMN mode is active, otherwise change the modality to P300 by choosing **[Protocol > Modality > Auditory P300/MMN > P300]** from the SmartEP main menu. Some of the Settings can be found by clicking on the **[Setup P300]** button that will appear on the top left of the Control Panel.

- **Buffer 0**: 1000 Hz (frequent tone). Click on the **[File]** button corresponding to this buffer from the setup window to set the stimulus.
- **Buffer 1**: 4000 Hz (deviant tone). Click on the **[File]** button corresponding to this buffer from the setup window to set the stimulus.

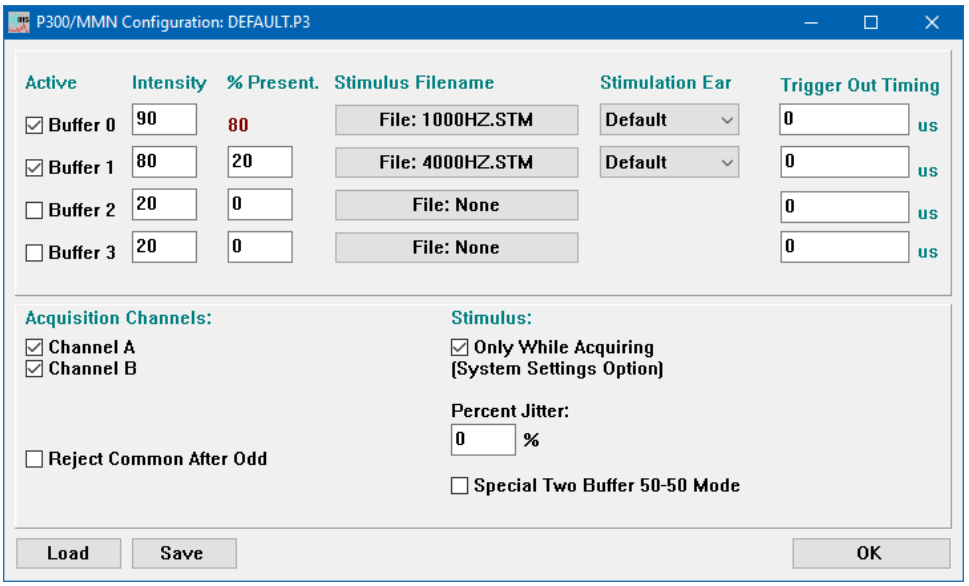


Figure 49 - [Setup P300] window

- **Percentage Presentations**: 80% for Buffer 0 (frequent) and 20% for Buffer 1 (deviant). Only the value for Buffer 1 needs to be entered in the **[% Present]** field in the setup window, the value for Buffer 0 will be calculated automatically.
- **Intensity**: ≥ 70 dB HL. Disparities between the frequent and deviant tones can be used. Values can be entered in the respective **[Intensity]** fields inside the setup window.
- **Channels**: Make sure to activate the channels used for data recording from the **[Setup P300]** window, only the active channels will yield a waveform.
- **Only While Acquiring**: keep this box checked so the stimulus is only presented once the **[Acquire]** button is pressed; otherwise, the stimulus from Buffer 0 will be presented continuously.
- **Rate**: 1.1/sec., 0.3/sec. if a longer ISI is needed.
- **Polarity**: Alternating.
- **Transducers**: Insert Earphones. The transducer choice can be made in the Auditory Stimulus Generation window by clicking on the **[Stim]** button on the control panel. Ignore the stimulus type in this window as the stimulus to be used will be coming from the **[Setup P300]** window.
- **Presentation Ear**: Monaural.
- **Filters**: 1-30 Hz, or 1-100 Hz.
- **Notch Filter**: OFF. ON only if there is excessive electrical line noise present.

- **Gain**: 50x.
- **Analysis** Time Window: 500 ms.
- **Sweeps**: 100 total. Can be divided into smaller batches then added up post-acquisition.
- **Montage**: Ipsilateral Array.
- **Jitter**: 0%, only add if protocol requires it.
- **Trigger Out Timing**: 0.
- **Reject Common After Odd**: Active

Special 50-50 Modes

When presenting two stimuli at equal rates, there are multiple options for presentation sequences for the stimulus buffers 0 (B0) and 1 (B1):

- When setting the presentation to 50%, without activating the special 50-50 mode, the B0 and B1 stimuli will be presented randomly.
- When activating the Special Two Buffer 50-50 Mode, the presentation sequence will no longer be randomized, instead a repeating sequence of B0-B0-B1 will be presented; where the first B0 presentation will have its corresponding sweep rejected.
- Deactivating the Reject Common After Odd option while the Special 50-50 mode is active will modify the presentation to a B0-B1 repeating sequence, as the first B0 presentation is no longer needed.

MMN settings

Before changing any settings, change the modality to P300 by choosing **[Protocol > Modality > Auditory P300/MMN > MMN]** from the SmartEP main menu. Some of the Settings can be found by clicking on the **[Setup P300]** button that will appear on the top left of the Control Panel.

- **Buffer 0 and Buffer 1**: Slightly different Tones, or Speech files. Click on the **[File]** button corresponding to each buffer to select the stimuli.
- **Percentage Presentations**: 80% for Buffer 0 (frequent) and 20% for Buffer 1 (deviant). Only the value for Buffer 1 needs to be entered in the **[% Present]** field in the setup window, the value for Buffer 0 will be calculated automatically.
- **Intensity**: ≤ 70 dB HL. Disparities between the frequent and deviant tones can be used. Values can be entered in the respective **[Intensity]** fields inside the setup window.
- **Channels**: Make sure to activate the channels used for data recording from the **[Setup P300]** window, only the active channels will yield a waveform.
- **Only While Acquiring**: keep this box checked if presenting the stimulus only once the **[Acquire]** button is pressed; keep in unchecked to have the stimulus from Buffer 0 presented continuously.
- **Rate**: 1.1/sec, 0.3/sec if a longer ISI is needed.
- **Polarity**: Rarefaction.
- **Transducers**: Insert Earphones are preferred; Headphones can also be used. The transducer choice can be made in the Auditory Stimulus Generation window by clicking on the **[Stim]** button on the control panel. Ignore the stimulus type in this window as the stimulus to be used will be coming from the setup window.
- **Presentation Ear**: Monaural.
- **Filters**: 1-30 Hz.
- **Notch Filter**: OFF.
- **Gain**: 50x.
- **Analysis** Time Window: 500 ms.
- **Sweeps**: 100 to 500. Less sweeps are needed for quiet, normal-hearing, patients.
- **Montage**: Ipsilateral Array.
- **Jitter**: 0%, only add if protocol requires it.

- **Trigger Out** Timing: 0.
- **Reject Common After Odd**: Active

Saving settings for P300/MMN

There are two independent sets of parameters used for P300 and MMN acquisition, the stimulation parameters from the setup window and the acquisition parameters from the control panel. To save your settings for future use:

1. Open the Setup P300 window and
2. With all fields already set to the correct values, click on the **[Save]** button to save the stimulation settings. Give the file a descriptive name that reflects the setting used. Leaving the file name as "DEFAULT.P3" will save the settings as the default P300 settings, which will load any time the modality is changed to P300/MMN. The P300 and MMN settings files have a ".P3" extension.
3. Close the P300 Setup window.
4. Click **[Save Settings**] from the control panel to save the acquisition settings. Give the file a descriptive name that reflects the settings used.

Loading settings for P300/MMN

To load settings for P300 or MMN:

1. Click on the **[Load Settings]** button from the control panel and choose the P300 or MMN settings file. Loading this file will change the acquisition modality automatically.
2. Click on the **[Setup P300]** button.
3. From the Setup P300 window click on the **[Load]** button and choose the correct stimulation settings file from the list.
4. Close the window by clicking **[OK]** and start the acquisition.

Marking peaks

P300 labeling

When P300 recordings are acquired, the resulting average will be two waveforms, as seen in Fig. 71. One of them will be labeled as 'Buffer 0' (B0), and another 'Buffer 1' (B1). Each of these averages corresponds to the stimulation buffers that were defined in the P300 setup window.

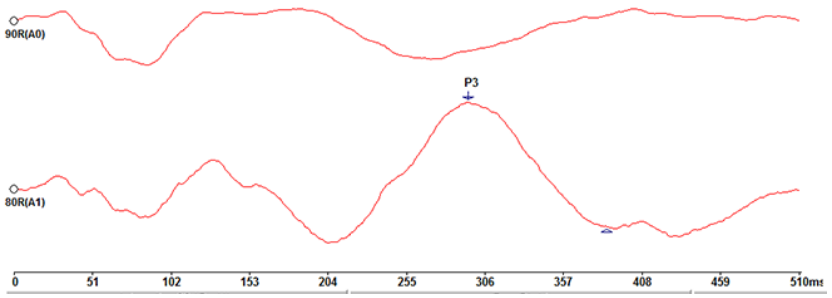


Figure 50 - P300 waveform with peak labels

The expected result, as shown on the previous figure, is that the average corresponding to the deviant stimuli (the one the patient should count or pay attention to), contains peaks that are not present on the averages corresponding to the common stimuli. Make sure to add together the waveforms corresponding to the same buffers if the acquisition was done in batches.

The most notable feature in the waveform is the P300 (also referred to as P3) peak, which occurs at about 300 milliseconds from stimulus onset. Do not forget to drag the bottom marker to the following valley so the software can calculate the amplitude of the peak.

MMN labeling and area calculation

The resultant of a Mismatched Negativity acquisition will be, as with P300, one recording per stimulus used; generally, one standard (B0) and one deviant stimulus (B1). The measurement of significance may be hard to assess visually, as with other evoked responses. For this reason, the area of the difference between the waveforms of the standard and the deviant responses is calculated.

1. Select both waveforms by holding the **[Ctrl]** key on your keyboard and clicking on them or their handles.
2. From the SmartEP main menu, select **[Process > Subtract Selected]** or simply press the **[-]** key on your keyboard.
3. If the resulting waveform is upside down (refer to the recording shown on Fig. 75), select **[Process > Invert Selected]** from the main menu.
4. Mark the start of the MMN area by placing the MMN marker at the start of the valley.
5. Drag the bottom marker to the end of the valley using the left mouse button.

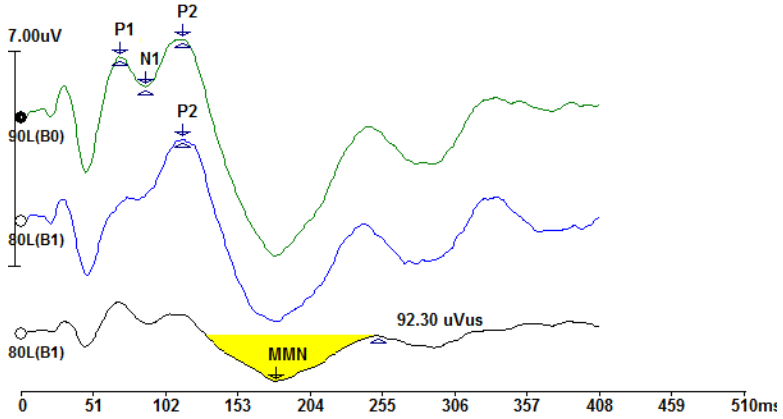


Figure 51 - MMN waveform and labels

6. The area over the curve is calculated automatically and shown in yellow. The calculated area value is shown next to the bottom marker in microvolts per microsecond.
7. You can also mark the original recordings with P2 and N1 labels for reference.

Chain Stimuli Modality

11

Chain Stimuli is an added modality of SmartEP. It is used to run a concurrent acquisition of different intensity ABR recordings. The intensities are interleaved, resulting in multiple waveforms acquired at the click of a single button.

Suggested electrode placement

This modality is simply a different way to acquire ABR waveforms. Use the exact same setup that would be used for standard ABR acquisition. Refer to AEP Electrode Placement on page 26 for details.

Patient state

A Chain Stimuli modality session has the same requirements as a standard ABR recording session. See Patient State on page 21.

Settings for acquisition

Before changing any settings make sure the Chain Stimuli mode is active, otherwise change the modality to by choosing **[Protocol > Modality > Auditory - Chain Stimuli]** from the SmartEP main menu. Some of the Settings can be found by clicking on the **[Setup Chain]** button that will appear on the top left of the Control Panel.

Settings in the "Setup Chain" window

- **Buffer 0-9**: The check boxes are used to activate and deactivate the buffers to use, where each buffer corresponds to one intensity value. E.g.: If doing a chain of 5 intensities, only 5 of these boxes should be checked corresponding to the intensities needed.
- **Intensity 0-9**: These fields can be used to enter the intensities to be used for acquisition. By default, the fields will be pre-filled to values between 0 and 90 in ten dB steps. Intensities can be entered in 1 dB steps. Intensity values can be repeated if necessary.

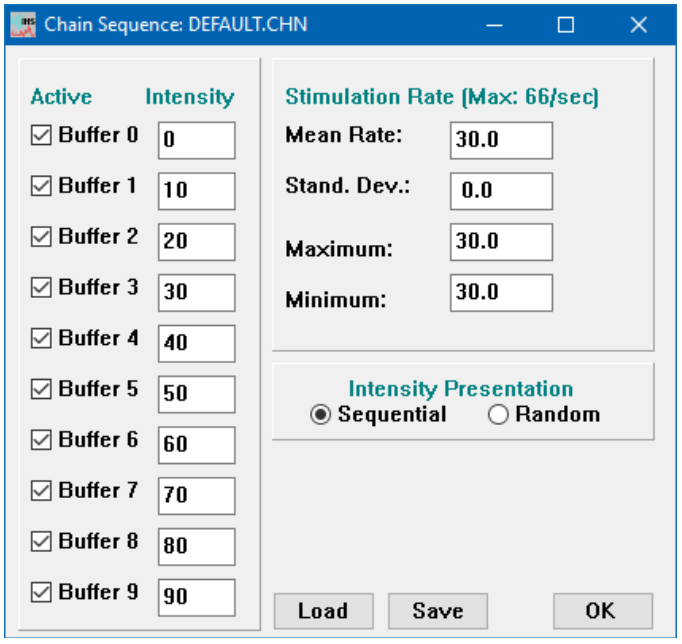


Figure 52 - Setup Chain window

- **Mean Rate**: This is the average rate of acquisition that will be used by the software. This is equivalent to the rate value used when acquiring ABR in standard mode. This setting should not exceed the value

shown above it, the allowed maximum. If using a constant rate, the most common use, set this value to be the same as the "Maximum" and "Minimum", while keeping the "Standard Dev" value at 0.

- **Standard Dev**: This setting should normally be set to 0. Only enter a value for standard deviation when performing an acquisition with variable rate. This value, in combination with the mean rate, will shape the bell curve used to randomly vary the acquisition rate.
- **Maximum**: This setting should be equal to the "Mean Rate" for normal acquisition. If using a variable acquisition rate, then enter the maximum rate that the system should use. This value should always be equal or higher than the "Mean Rate" field.
- **Minimum**: This setting should be equal to the "Mean Rate" for normal acquisition. If using a variable acquisition rate, then enter the minimum rate that the system should use. This value should always be equal or lower than the "Maximum" field.
- **Intensity Presentation**: "Sequential" acquisition is the most commonly used, it will start the presentation at the 'Buffer 0' intensity value and end at the 'Buffer 9' intensity value, for the buffers that are active. Selecting "Random" will make the software randomly choose one of the active buffer intensities as it goes, always keeping the total number of sweeps even between all buffers.

Example setup

The following image shows an example setup for Chain Stimuli. The settings shown will result in an intensity series from 90 dB to 10 dB, in 20 dB steps. The units, SPL or HL, are defined by the settings in the Auditory Stimulus Generation window. The chain is ramping up from 10 to 90 at a rate of 21.1 presentations per second. There is no variability (all rate values are equal), and there is no randomness in the presentation of the stimuli corresponding to each buffer.

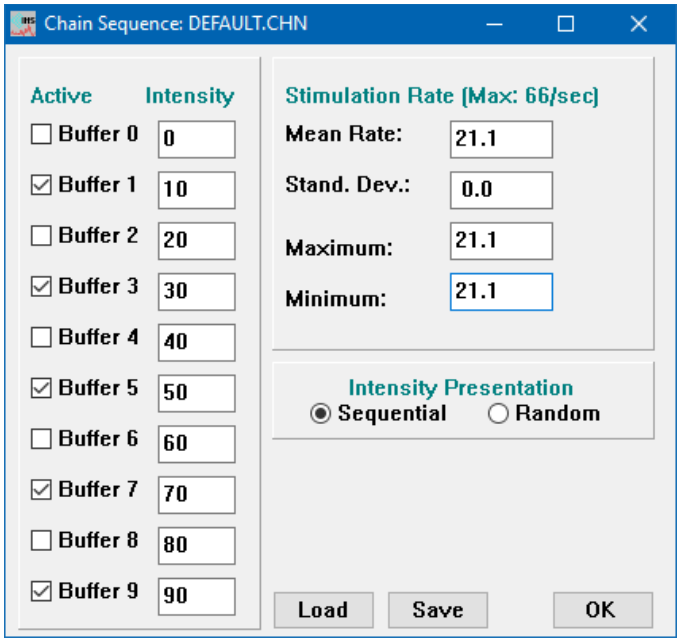


Figure 53 - Chain Sequence window

Settings in the Control Panel

The following settings remain in the Control Panel. They are used the same as they would in standard ABR acquisition:

- **Sweeps**: this value will determine the number of sweeps that each one of the recordings will total to when acquisition is completed.
- **Ear**: one at a time.
- **Mode**: Ipsi (unless present conditions prevent it).
- **Stim**: clicks, tones or files as needed; same as Standard ABR.
- **Phase**: same as standard ABR.
- **Amplifier**: Filters, Gain, and Rejection Region same as with standard ABR.

Saving settings for Chain Stimuli

There are two independent sets of parameters used for Chain Stimuli acquisition, the stimulation parameters from the setup window and the acquisition parameters from the control panel. To save your settings for future use:

1. Open the **[Setup Chain]** window and
2. With all fields already set to the correct values, click on the **[Save]** button to save the stimulation settings. Give the file a descriptive name that reflects the setting used. Leaving the file name as "DEFAULT.CHN" will save the settings as the default Chain Stimuli settings, which will load any time the modality is changed to Chain Stimuli. The Chain Stimuli settings files have a ".CHN" extension.
3. Close the 'Setup Chain' window.
4. Click **[Save Settings]** from the control panel to save the acquisition settings. Give the file a descriptive name that reflects the settings used.

Loading settings for Chain Stimuli

To load settings for Chain Stimuli:

1. Click on the **[Load Settings]** button from the control panel and choose the Chain Stimuli settings file. Loading this file will change the acquisition modality automatically.
2. Click on the **[Setup Chain]** button and verify the stimulation settings have loaded properly.
3. From the Setup Chain window click on the **[Load]** button and choose the correct stimulation settings file from the list.
4. Close the window by clicking **[OK]** and start the acquisition. Make sure to change your stimulation parameters if necessary.

Stimulus sequences

Sequential chain sweep

The timeline of the stimulus for a sequential chain stimulus setup is shown below. Each S value represents a stimulus as defined in the 'Setup Chain' window. In this case there are 5 active buffers (B0 to B4), resulting in 5 stimuli with different intensities. This will result in 5 separate recordings, one corresponding to each active intensity value (buffers). The chain will repeat as shown until the full number of sweeps is completed.

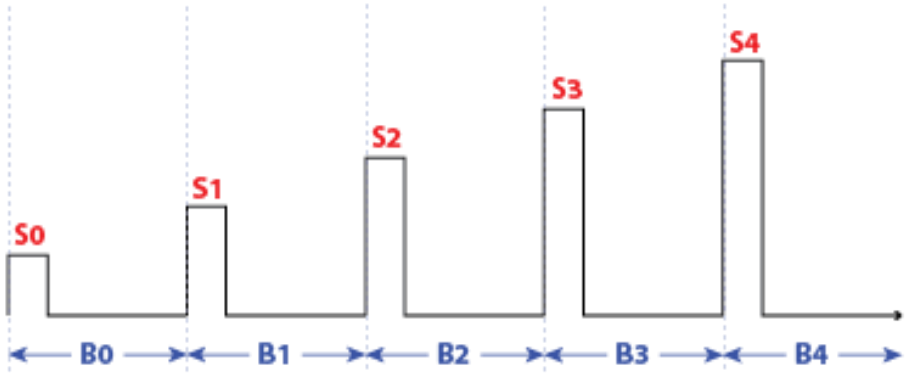


Figure 54 - Stimulus timeline for a chain-stimuli sequence

Random chain sweep

A possible timeline of the stimulus for a random chain stimulus setup is shown below. Each S value represents a stimulus as defined in the 'Setup Chain' window. In this case there are 5 active buffers (B0 to B4), resulting in 5 stimuli with different intensities. This will result in 5 separate recordings, one corresponding to each active intensity value (buffers). The random timeline will change with every sweep, continuing to acquire random stimulus sequences until the full number of sweeps is completed.

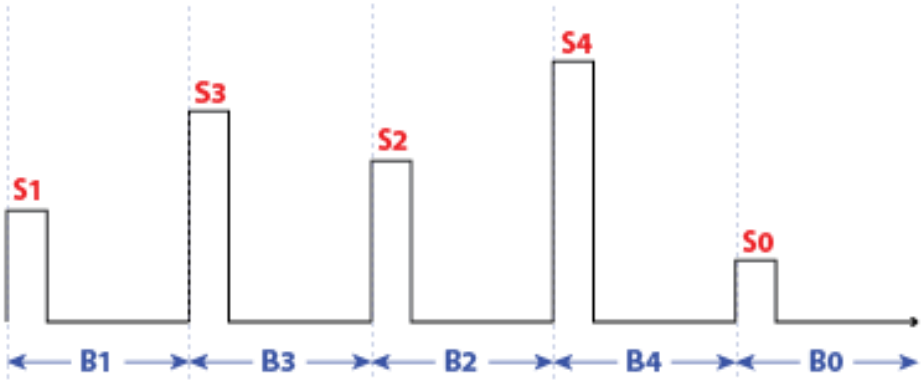


Figure 55 - Stimulus timeline for a random chain-stimuli sequence

Chain acquisition

As with standard ABR mode, simply click the **[Acquire]** button on the control panel. While is it running, the sweep count will increase, and the main screen will show one waveform per active buffer.

Marking peaks

Peak marking for recordings acquired with Chained Stimuli will be no different than standard ABR recordings. See Waveform Identification

There are multiple ways to recognize the modality and parameters that were used to acquire a recording, including the text indicators at the start of the plot and the color of the plotted waveform.

The indicators at the start of the waveform include multiple data markers. The stimulus information and acquisition rate can be shown or hidden using the options in the main menu under **[Show > Show Recording Label]**. The first line, includes the following information:

- The intensity of the stimulus in dbs. The number will show the nominal value whether the stimulus was presented in HL or SPL.
- The channel of acquisition in parenthesis; this is also indicated by the color of the plot, typically red for right, blue for left and black for both. Note that the selected waveform will always be a green plot.
- The mode of acquisition, whether it was ipsilateral (Ipsi) or contralateral (Contra). When acquiring from both sides, there will be no indicator, as shown in the third waveform on the right.

The second line of text, the stimulus information will include the following:

- If the stimulation was delivered via air conduction (AC) or bone conduction (BC). If you wish to see the stimulator choice, right click on the waveform, and look at the recording information option.
- The stimulus type, whether it is click, a generated frequency or the name of a loaded STM file.
- When using a generated tone burst (second waveform in the example) the envelope used will be indicated in parenthesis. In case example above, the 500Hz tone was presented using envelope code 7, or Blackman.
- The polarity of presentation, where the options are rarefaction (R), condensation (C), and alternating (A). For waveforms acquired using the Advanced Auditory modality (fourth waveform in the examples) the polarity of each component is shown after the stimulus name. Each digit corresponds to each component's polarity matching the order on the setup window, where 0 is alternating, 1 is rarefaction, 2 is condensation, and 8 means the stimulus component is OFF,

The third line shows the rate of acquisition. If the waveform is tagged as KEEP, using the right-click context menu, the marker will appear as the last line, as shown in the third waveform above.

Any additional information about the waveform acquisition and stimulation settings can be obtained by using the recording information panel located on the right-hand side of the screen. If the panel is not open, click on the **[Rec Info]** button to make it available. Additionally, right-clicking on the waveform will open the context menu, with all the data listed on the file name and information item at the top of the menu.

Placing labels on page 56 for details.

Triggered eABR Modality

12

In eABR modality the stimulation is provided by the cochlear implant equipment, while the averaging is completed by SmartEP. Alternatively, this module could be used to record while synchronizing to external hardware that provides the correct trigger signal.
Hardware connections

In order to use the eABR mode:

- The IHS hardware must be connected to the Cochlear Implant (CI) computer using the trigger input. This trigger input is a connector which needs to receive a 5-volt TTL pulse in order to activate. Refer to the technical reference for your unit for additional information about the eABR trigger input cable.
- Connect surface electrodes as you would when acquiring an ABR, while keeping the recording electrodes away from the stimulation sites. See the suggested AEP Electrode Placement on page 26 for details.
- Connect the CI machine to the CI processor. Most CI manufacturers will include instructions on how to perform this setup. Contact the CI manufacturer representative for additional details.

Setting acquisition parameters

Although all operating parameters are set on the CI computer, it is important to set the same parameters in the SmartEP software to keep as a reference for each recording.

1. Before starting acquisition, set the modality by clicking on **[Stimulus > Modality > Auditory eABR]** from the main menu, selecting the option that applies for the type of recording to be obtained.
2. Using the buttons on the control panel, set the parameters for the test such as intensity, rate, mode, stimulus type, and number of sweeps.
3. Click on the **[Acquire]** button in the SmartEP control panel to activate the trigger detection.
4. Enter the stimulation parameters on the CI computer, matching the settings entered in SmartEP. The number of stimuli presentations provided by the CI must be equal or greater than the number of sweeps selected in SmartEP.

Electrode placement

Placing the electrodes away from the implant minimizes the effects of electrical artifact caused by the stimulus. Some implant manufacturers prefer a contralateral placement to a midline placement; both methods should achieve usable responses with slightly different morphology. Verify electrode placement recommendations with the CI manufacturer as they may differ from the setups suggested here.

Midline placement

Using a USB Jr. Duet

For this setup, open the Amplifier Settings window and set the designation of channel being used (Channel A for Right, Channel B for Left) to ON. The opposite channel should be set to OFF. The 5-electrode lead patient cable and a Y-adapter is required for this setup.

- **Inverting (-)**: at Cz. Red for a right ear setup, Blue for a left ear setup.
- **Non-inverting (+)**: at the back of the neck. White for a right ear setup, Grey for a left ear setup.
- **Ground (⏚)**: at the forehead (Fpz). Black snap electrode lead.
- Unused channel: connect a Y-adapter between the inverting and non-inverting positions of the channel not being used. Joint end is left unconnected.

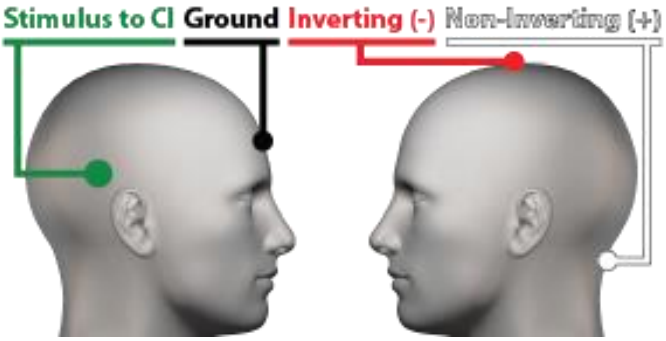


Figure 56 - eABR Midline placement, right ear, on Duet

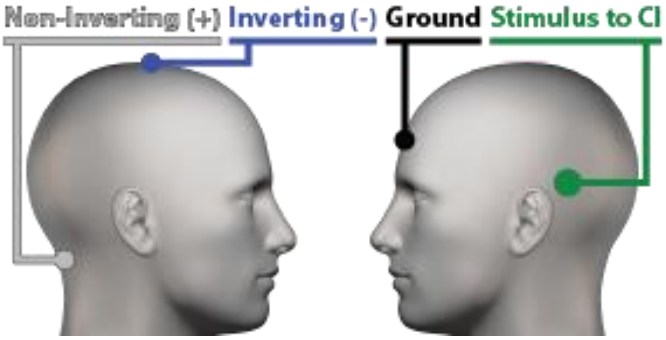


Figure 57 - eABR Midline placement, left ear, on Duet

Using a single channel Opti-Amp on USB and USB Jr.

- **Inverting (-)**: at Cz. Red socket when testing right, blue socket when testing left.
- **Non-inverting (+)**: at the back of the neck. Black electrode socket.
- **Ground (⏚)**: at the forehead (Fpz). Blue when testing right, Red when testing left.

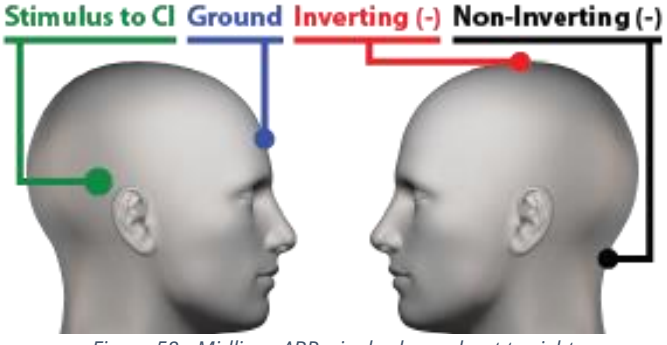


Figure 58 - Midline eABR, single channel, set to right

Using a dual or multi-channel Opti-Amp on USB or USB Jr.

- **Inverting (-)**: at Cz. Red electrode socket of channel being used.
- **Non-inverting (+)**: at the back of the neck. Blue electrode socket, for the channel being used.
- **Ground (⏚)**: at the forehead (Fpz). Black electrode socket.
- **Unused Channels**: any unused channels should be shorted by plugging in a Y-Adapter between the inverting and non-inverting positions. Joint end is left unconnected.

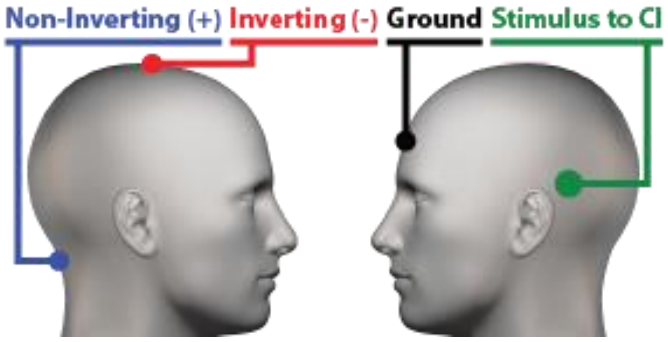


Figure 59 - Midline eABR, dual or multi-channel transmitter

Contralateral placement

Using a USB Jr. Duet

For this setup, when testing right, the designation of Channel A should be set to ON, and Channel B to OFF in the Amplifier Settings window. When testing left, the designation of Channel B should be set to ON, and Channel A to OFF in the Amplifier Settings window.

- **Inverting (-)**: to the contralateral mastoid. Red for a right ear setup, Blue for a left ear setup.
- **Non-inverting (+)**: at the forehead (Fpz). White for a right ear setup, Grey for a left ear setup.
- **Ground (⏚)**: at the back of the neck. Black lead.

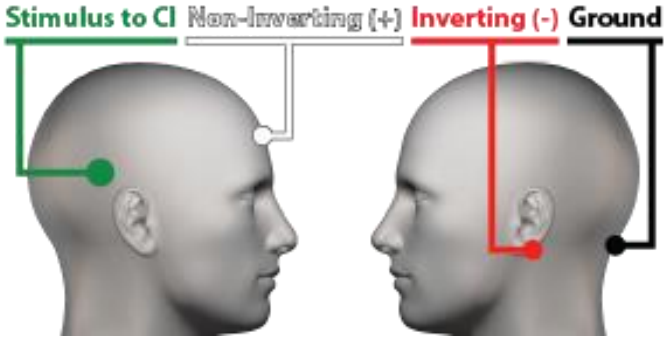


Figure 60 - Right ear - contralateral electrode placement for eABR

It is also possible to implement this setup, when using the 5-position cable, in a way that sends data to both channels; in this case, the Red and Blue sockets need to be joined using a Y-adaptor and placed on the contralateral mastoid, a second y-adaptor should be use to join the White and Grey sockets and placed at the forehead.

Using a single channel Opti-Amp on USB and USB Jr.

- **Inverting (-)**: to the contralateral mastoid. Red socket when testing right. Blue socket when testing left.
- **Non-inverting (+)**: at the forehead (Fpz). Black socket.
- **Ground (⏚)**: at the back of the neck. Blue socket when testing right. Red socket when testing left.

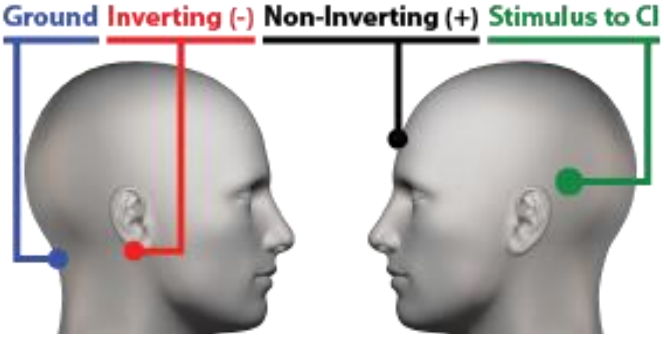


Figure 61 - Contralateral electrode placement for eABR, left ear test

Using a dual or multi-channel Opti-Amp on USB or USB Jr.

- **Inverting (-)**: to the contralateral mastoid. Red electrode socket of the channel being used.
- **Non-inverting (+)**: at the forehead (Fpz). Blue electrode socket of the channel being used.
- **Ground electrode (⏚)**: at the back of the neck. Black electrode socket.

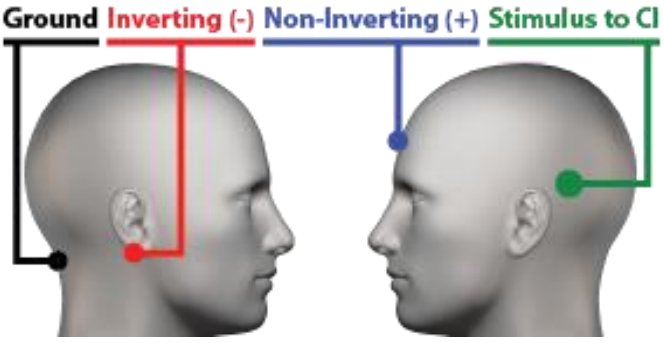


Figure 62 - Contralateral electrode placement for eABR using dual or multi-channel transmitter.

Patient state

As with standard AEP acquisition, the patient must be placed in a quiet environment, where the patient lies down on a comfortable bed or recliner chair. The patient must be instructed to relax during testing. It is best that the patient avoids stimulants, such as caffeine, before acquisition.

Starting and stopping acquisition

Once all parameters are entered on both machines, the SmartEP software needs to be set to acquire before starting stimulation. To pause acquisition simply pause the stimulation, doing so will stop sending the TTL trigger signals to the USB box, effectively pausing the acquisition. To stop the acquisition, stop the stimulation first in the CI machine, then press the Stop/Pause button in SmartEP and follow the software prompts.

The Amplifier Blanking Time

When acquiring eABR, the software will activate a feature called blanking time. This refers to the length of time that a reduced gain will be applied to the incoming signal. Minimizing the gain during this time prevents the amplifier from over-saturation. The setting can be changed by clicking on **[Stimulus > Blanking Time]** from the SmartEP main menu. The time should be entered in microseconds and should not exceed the onset of the expected structure of the response.

Marking peaks

Peak labeling on an eABR recording is the same as with any standard AEP. The only difference in the recordings is that the area of the waveform covered by the blanking time will have greatly reduced amplitude, or contain a large stimulus artifact, preventing the recognition of any repeatable electrophysiological components in the response. To mark a peak use one of these two methods:

- Using the marker buttons on the toolbar. First select the recording that you wish to label, the markers shown may update to reflect the selected recording type. Click on the label button (on the toolbar) once, then click just above or below the location where you want the label's top marker to be placed. Once the label is in place, left-click-hold and drag the bottom marker to its proper location.
- With the recording selected, right click on the location where you want the label's top marker to be placed. From the context menu, select either **[Mark Peak]** and the standard label you wish to place, or **[Mark Other Peak]** to select from non-standard labels. Once the label is in place, left-click-hold and drag the bottom marker to its proper location.

Vestibular Evoked Myogenic Potential

13

This modality is available as an add-on for the USB Jr. Duet and USB Box hardware platforms; it is not available for the USB Jr., Solo, or USBLite. Some consideration must be given to patient safety before starting any type of electrical stimulation protocol.

VEMP

Vestibular evoked myogenic potentials (VEMPs) are short-latency electromyograms (EMGs) recorded via surface electrodes from the tonically contracted anterior neck muscles of a patient (most commonly the sternocleidomastoid or SCM muscle), in response to acoustic stimuli presented at relatively high levels (typically 95-110 dB nHL or louder) and slow repetition rates (2-5 per second). The acoustic stimulus delivered to the ear may come in the form of broadband clicks and/or low frequency tone bursts, delivered via either air or bone-conduction. As in the case of AEP testing, the evoked response (EMG) is recorded through the use of electrodes placed on the patient, amplified, filtered, digitized, and averaged with multiple responses to obtain a final evoked response signal.

The tonic state of the anterior neck muscles is a critical parameter in the recording of cervical vestibular evoked myogenic potentials (cVEMP) and must be tonically contracted in order to invoke a proper VEMP response. If the neck muscles are not properly activated, little or no VEMP is produced. Therefore, controlling the level of tonic EMG baseline is a prerequisite for the accurate generation and interpretation of the VEMP. For this purpose, the system uses a VEMP feedback box and/or computer monitor to provide a visual feedback mechanism for the test administrator to assess the tonic state of the test subject's anterior neck muscle EMG activity during testing. This feedback simply indicates "satisfactory" when proper muscle activation is achieved or "unsatisfactory" otherwise. VEMP responses may also be recorded by placing an electrode near the inferior oblique muscle, these responses are called ocular VEMP (oVEMP)

Starting the module

To start the SmartVEMP module for SmartEP, do the following:

1. Using the Launch Pad program, it is recommended that you either create or load an existing patient before proceeding.
2. Click on the **[SmartEP]** button at the bottom of the Launch Pad program.
3. Once SmartEP has finished loading, click on **[Protocol > Modality]** from the main menu. Then choose one of the VEMP options.
4. The software will change to the default settings for the SmartEP modality and show the patient feedback window.

Skin preparation for surface electrodes

When using surface electrodes, be it disposable or reusable, it is imperative to achieve good impedance values. This will lead to less recording noise, and more repeatable responses. Here are some recommendations for reducing skin impedance. Make sure you adhere to your institution's standard procedures for skin preparation as they supersede any recommendations IHS may provide:

- Gently clean the skin with an alcohol pad to remove excess oil or makeup at the intended electrode placement locations.
- If necessary, mildly rub the electrode locations with a soft cloth pad such as gauze and some approved impedance reducing abrasive gel. Be mindful of specific patient needs for skin sensitivity and follow the gel manufacturer's instructions. You want to skip this altogether when the patient is a newborn, small infant, or any patients with extremely sensitive skin.
- When using disposable electrodes, make sure they are not expired. Expired electrodes may result in noisy recordings, bad impedances, or detaching electrodes.
- You may place a small dab of approved conductive gel on the electrode sensor area of the disposable electrodes before placement to improve impedance. Do not use too much gel or it may prevent the electrode from sticking. Letting the electrodes sit in place for a few minutes may help the conductive gel settle and improve impedances.
- Do not press disposable electrodes onto the skin by the sensor area, use the sides of the electrode. Pressing the sensor area may force any conductive gel into the adhesive area, causing the electrode to fail to adhere, or to detach later mid-test.
- When using gold cup electrodes, or similar, make sure to use enough conductive paste and then secure them in place by using a small piece of surgical tape. Using a small piece of gauze between the electrode and the surgical tape is recommended.

Electrode polarity and locations

cVEMP

The following suggested cVEMP electrode placement locations are from:

Akin, F. W., & Murnane, O. D. (2008). Vestibular Evoked Myogenic Potentials. In G. P. Jacobson, & N. T. Shepard (Eds.), Balance Function Assessment and Management (pp. 405-434). San Diego, CA: Plural Publishing, Inc.

- **Inverting (-)**: sternoclavicular junction.
- **Non-Inverting (+)**: midpoint of the SCM muscle of the side being evaluated.
- **Ground (⏚)**: Forehead (Fz).

Guidance for Duet

This setup uses the 5 Electrode Leads Patient cable.

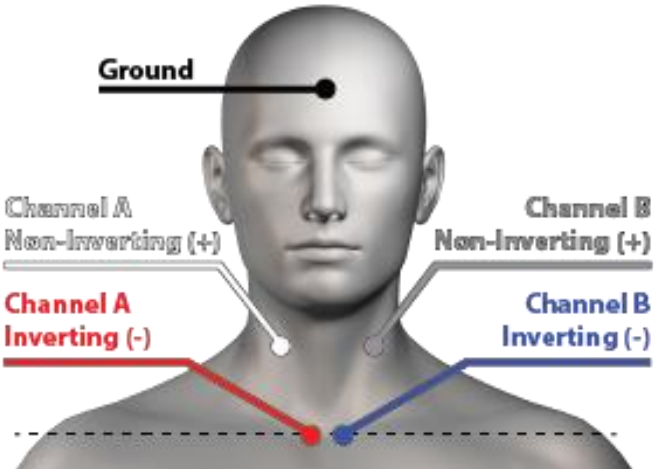


Figure 63 - cVEMP setup for Duet

- **Red (-)**: to right side of sternoclavicular junction.
- **Blue (-)**: to left side of sternoclavicular junction.
- **White (+)**: to midpoint of right SCM muscle, keep horizontal level to Grey.
- **Grey (+)**: to midpoint of left SCM muscle, keep horizontal to White.
- **Black (⏚)**: to forehead (Fz).

Alternatively, a Y-adapter cable could be used to jump the Red and Blue inverting electrode positions to a single electrode, as shown in Figure 64.

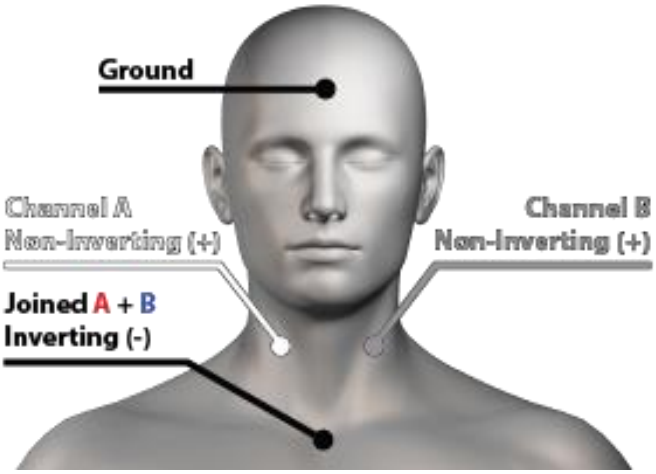


Figure 64 - Alternate cVEMP setup for Duet

Guidance for Dual and Multi-Channel Opti-Amp

A Y-adapter cable should be used to jumper the inverting electrode positions. Alternatively, two electrodes may be placed side to side at the junction.

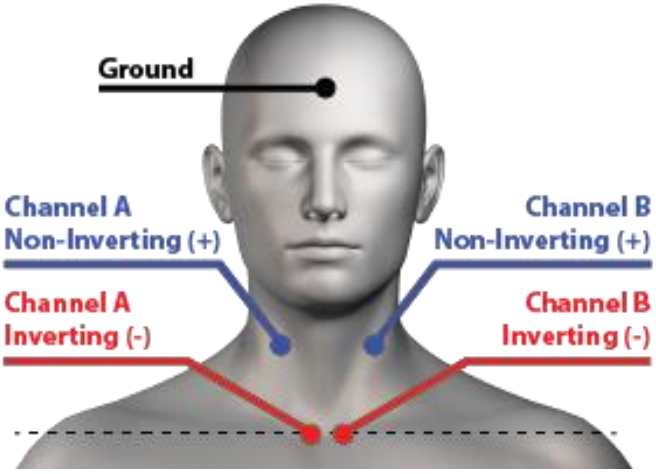


Figure 65 - cVEMP setup for two channels

- **Channel A Red inverting (-)**: to right side of sternoclavicular junction.
- **Channel B Red inverting (-)**: to left side of sternoclavicular junction.
- **Channel A Blue non-inverting (+)**: to midpoint of right SCM muscle, keep horizontal level to the other non-inverting electrode.
- **Channel B Blue non-inverting (+)**: to midpoint of left SCM muscle, keep horizontal to the other non-inverting electrode.
- **Black (⏚)**: to forehead (Fz).

Alternatively, a Y-adapter cable could be used to jump the Red inverting electrode positions to a single electrode, as shown in Fig. 90.

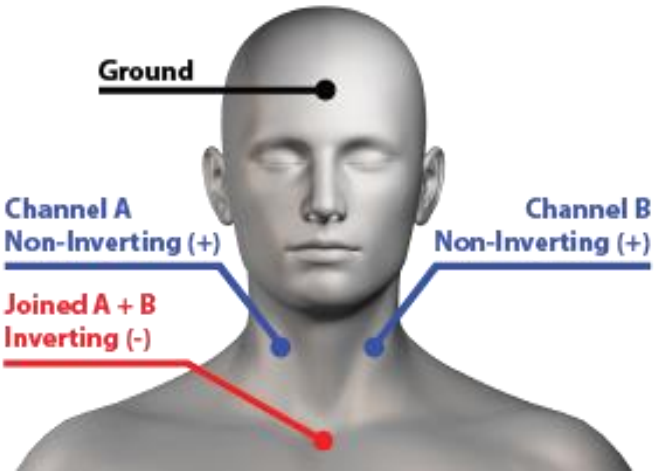


Figure 66 - Alternate cVEMP setup for two channels

When using a multi-channel transmitter, the inverting and non-inverting positions on the unused channels should be joined together using a Y-Adapter cable.

Guidance for Single Channel Opti-Amp

Left-Right switch on the Opti-Amp must be toggled to the stimulation side

For the left side, with the switch set to Left:

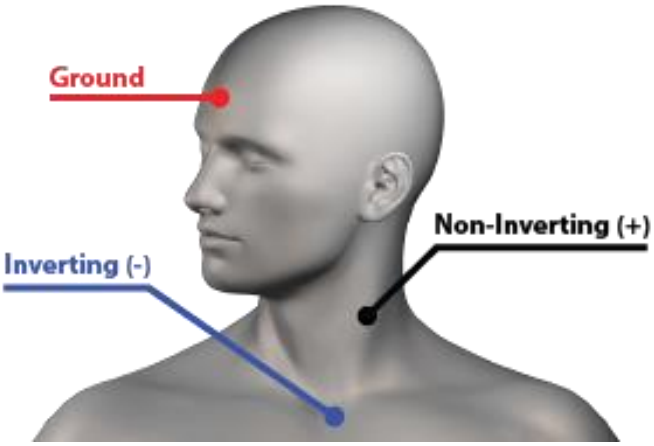


Figure 67 - cVEMP setup - left side - single channel Opti-Amp

- **Blue (-)**: to left side of sternoclavicular junction.
- **Black (+)**: to midpoint of left SCM muscle.
- **Red (⏚)**: to forehead (Fz).

For the right side, with the switch set to right:

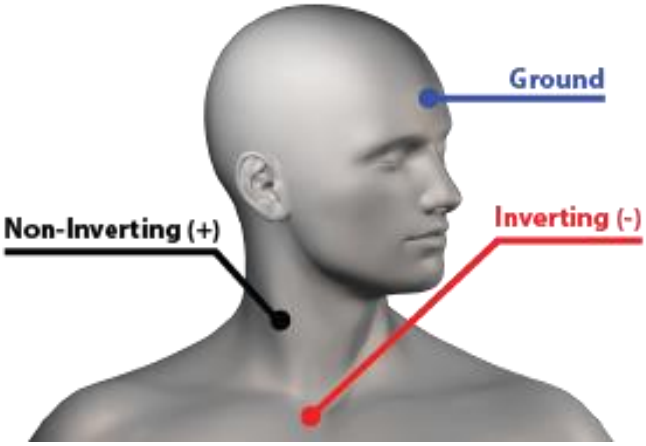


Figure 68 - cVEMP setup - right side - single channel Opti-Amp

- **Red (-)**: to right side of sternoclavicular junction.
- **Black (+)**: to midpoint of left SCM muscle.
- **Blue (⏚)**: to forehead (Fz).

Additional considerations

- Note that some users may prefer to use the inverse of the polarities indicated here; this will simply result in an inverted waveform to the ones shown in this manual.
- Electrodes for both sides may be placed before starting acquisition on either side, when using two channels.

oVEMP

The following suggested oVEMP electrode placement locations are from:

McCaslin, D. L., & Jacobson G. P. (2016). Vestibular Evoked Myogenic Potentials (VEMPs). In G. P. Jacobson, & N. T. Shepard (Eds.), Balance Function Assessment and Management (pp. 533-579). San Diego, CA: Plural Publishing, Inc.

- **Non-Inverting (+)**: infraorbital midline.
- **Inverting (-)**: 3 cm infraorbital (immediately below the infraorbital midline electrode) or chin.
- **Ground (⏚)**: Forehead (Fz).

Guidance for USB Jr. Duet

This setup uses the 5 Electrode Leads Patient cable. A Y-adapter cable should be used to jumper the inverting electrode positions. Note that using the 4 snap lead patient cable will lead to inverted recordings.

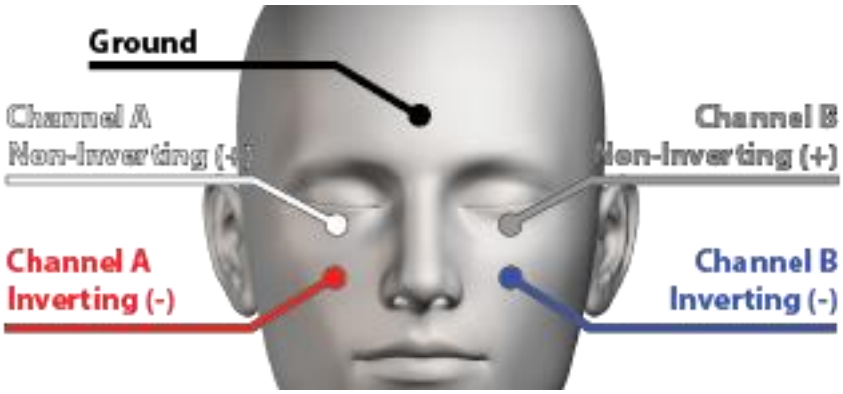


Figure 69 - oVEMP setup - Duet - infraorbital inverting

- **White (+)**: to right infraorbital midline.
- **Grey (+)**: to left infraorbital midline.
- **Red (-)**: to 3 cm from infraorbital right eye (below midline).
- **Blue (-)**: to 3 cm from infraorbital left eye (below midline.
- **Black (⏚)**: to forehead (Fz).

Alternatively, a Y-Adapter cable may be used to join the Red and Blue inverting positions to a single electrode on the chin, as shown in Figure 70.

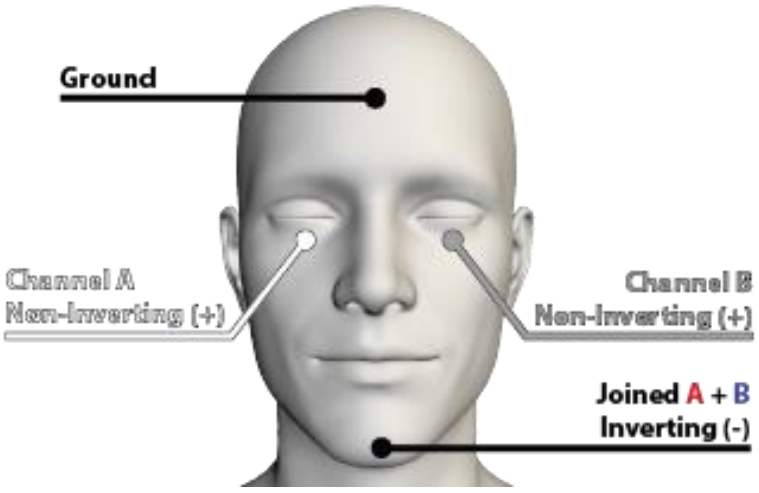


Figure 70 - Alternate oVEMP setup - Duet - chin inverting.

Guidance for Dual Channel Opti-Amp

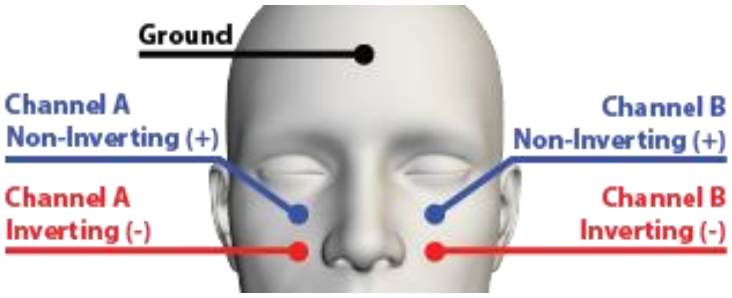


Figure 71 - oVEMP setup - 2 Ch. - Infraorbital inverting

- **Channel A Blue non-inverting (+)**: to right infraorbital midline.
- **Channel B Blue non-inverting (+)**: to left infraorbital midline.
- **Channel A Red inverting (-)**: to 3 cm from infraorbital right eye (below midline).
- **Channel B Red inverting (-)**: to 3 cm from infraorbital left eye (below midline.
- **Black (⏚)**: to forehead (Fz).

Alternatively, a Y-Adapter cable may be used to join the Red inverting positions to a single electrode on the chin, as shown in Fig. 96.

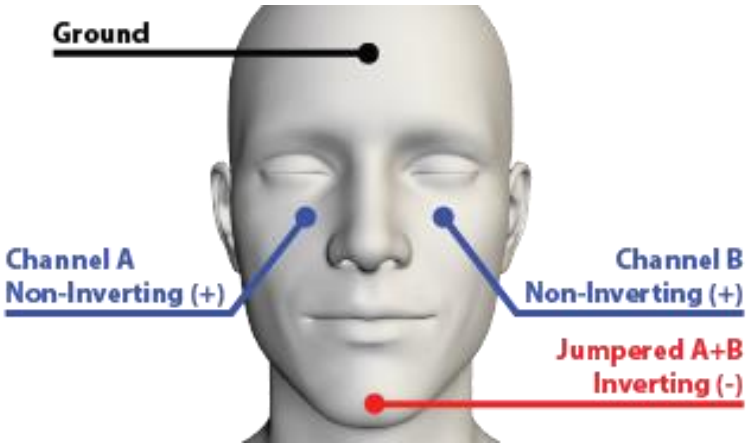


Figure 72 - Alternate oVEMP setup - 2 Ch. - Chin inverting

Guidance for Single Channel Opti-Amp

Left-Right switch on the Opti-Amp must be toggled to the stimulation side. For the left side, with the switch set to Left:

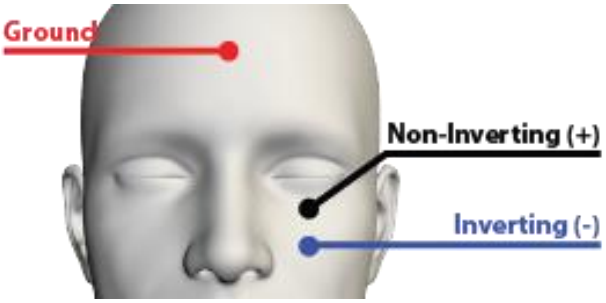


Figure 73 - oVEMP setup - left side - infraorbital inverting

- **Black (+)**: to left infraorbital midline.
- **Blue (-)**: to 3 cm from infraorbital right eye (below midline).
- **Red (⏚)**: to forehead (Fz).

For the right side, with the switch set to right:

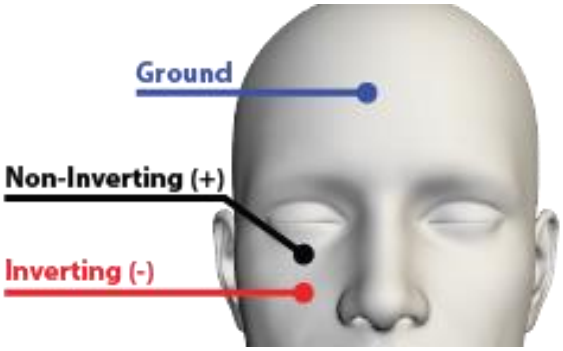


Figure 74 - oVEMP setup - right side - infraorbital inverting

- **Black (+)**: to left infraorbital midline.
- **Red (-)**: to 3 cm from infraorbital right eye (below midline).
- **Blue (⏚)**: to forehead (Fz).

Alternatively, the inverting electrode may be placed on the chin, as follows:

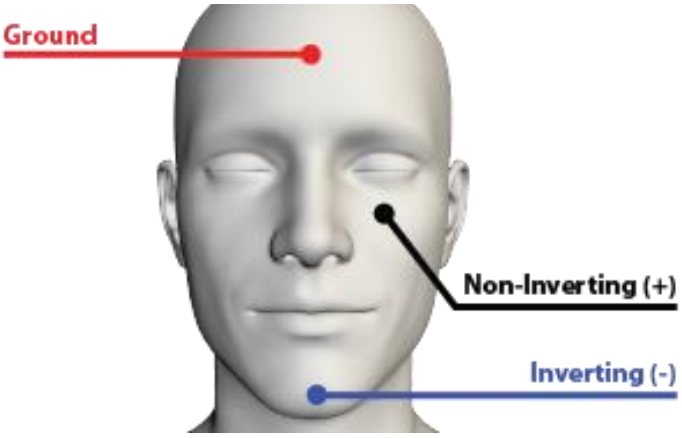


Figure 75 - oVEMP setup - left side - chin inverting

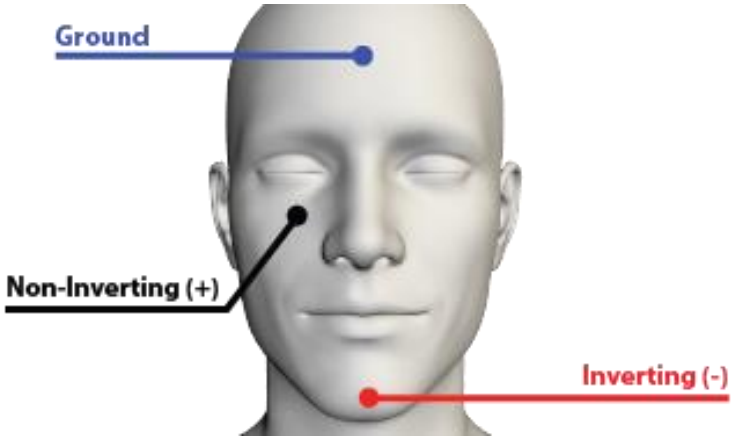


Figure 76 - oVEMP setup - right side - chin inverting

Additional considerations:

- Note that reversing the polarity of the electrodes will result on an inverted waveform.
- Electrodes for both sides may be placed simultaneously when using two channels.

Patient status

VEMP acquisition require patient participation, and therefore the patient needs to be awake. Common patient positioning is described below:

- Cervical VEMP (cVEMP): There are two common methods of activating the SCM muscle. The first is using head rotation to unilaterally activate the SCM muscle by having the patient turn their head away from the stimulated ear while either in the seated or supine position. The second method uses supine flexion to bilaterally activate the SCM muscles by having the patient raise their head against gravity in the supine position.
- Ocular VEMP (oVEMP): the patient should sit upright in a comfortable chair, where they are asked to fixate their vision to a point so that they are gaze upward.

Parameters for acquisition

Before changing the parameters, make sure to change the modality to VEMP by clicking on **[Protocol > Modality > VEMP]**, then choosing the appropriate type from the sub menu. The available stimulus envelopes for VEMPs are Blackman, trapezoidal (linear), triangular (linear), rectangular (linear), cosine squared (Hanning/Hann), and Gaussian.

cVEMP

The following suggested cVEMP acquisition parameters are from:

Akin, F. W., & Murnane, O. D. (2008). Vestibular Evoked Myogenic Potentials. In G. P. Jacobson, & N. T. Shepard (Eds.), Balance Function Assessment and Management (pp. 405-434). San Diego, CA: Plural Publishing, Inc.

Stimulus Parameters.

- 500 Hz Tone Burst
  - Polarity: Rarefaction
  - Intensity: 90-95 dB nHL
  - (120-125 dB peak SPL)
  - Rate: 5 per second
  - Mode: Ipsi
  - Rise/Fall: 2 cycles
  - Envelope: Blackman
- Click
  - Polarity: Rarefaction
  - Intensity: 95 - 100 dB nHL
  - (129 - 134 dB peak SPL)
  - Rate: 5 per second
  - Duration 100 us

Recording parameters:

- Gain: 5000 x
- High Pass Filter: 10 Hz
- Low Pass Filter: 1000 Hz
- Analysis time window: 100 ms
- Sweeps: 2 runs of 64 - 256 each
- Artifact Rejection: Off

oVEMP

The following suggested oVEMP acquisition parameters are from:

McCaslin, D. L., & Jacobson G. P. (2016). Vestibular Evoked Myogenic Potentials (VEMPs). In G. P. Jacobson, & N. T. Shepard (Eds.), Balance Function Assessment and Management (pp. 533-579). San Diego, CA: Plural Publishing, Inc.

Stimulus Parameters:

- Frequency: 500 Hz
- Intensity: 95 dB nHL
- Envelope: Blackman
- Rate: 5.1 per second

Recording parameters:

- Gain: 30,000 to 50,000 x
- High Pass Filter: 1 - 10 Hz
- Low Pass Filter: 500 - 1000 Hz
- Analysis time window: 100 ms,
- with a 20 ms pre-stimulus
- Sweeps: 2 runs of 150 each
- Artifact Rejection: enabled

Acquisition

VEMP acquisition requires patient participation, see the following sections for details. To start acquisition, simply hit the 'Acquire' button on the control panel. Both Left and Right waveforms are usually necessary for evaluation of VEMP responses.

To prevent fatigue, it is recommended that the sweeps be split into multiple acquisitions. Perform acquisition sets of 50 sweeps each, with a period of rest in between each set. When done, select all waveforms (for the same side) by clicking on their handles while holding down the 'Ctrl' key on the keyboard, then choose **[Process > Add Selected Recordings]** from the main menu to obtain a grand average. Make sure to save the new averaged waveform for future reference by using the save option in the data menu, or by saving a report. For easier identification, grand averaged waveforms will have a thicker line appearance than normal recordings. Make sure to acquire recordings for both Right and Left sides, as they are needed to perform the comparison.

Suggested patient instructions for cVEMP

Have the patient lay down at 30 degrees at baseline, have the patient lift and turn their head in the opposite direction to the stimulus (e.g., when stimulating the right ear, have the patient turn left).

It is possible to acquire from both sides simultaneously, the patient must lift their head while keeping their back in place, creating tension on both SCM muscles.

Proper muscle activation can be assessed by looking at the feedback tools, such as the VEMP feedback box or the EMG level feedback window. The patient must try to achieve a constant level of muscle activation.

Suggested patient instructions for oVEMP

When acquiring oVEMP the patient must be instructed to look up at a target up and in front of them and continue looking during the acquisition. For example, the target can be placed at approximately 36 inches away from the patient and 36 inches above their baseline to achieve a 45-degree angle. Blinking should be avoided as much as possible to prevent artifacts from contaminating the response.

Suggested setting for RMS Min and Max

Since each person will have a different range of motion and muscle tension, the minimum and maximum values for the RMS must be set for each patient individually. The recommended way of setting the values is to use the controls available in the VEMP EMG Level Feedback window. Values can also be entered manually, if desired.

To measure the level range, do the following:

1. Once the electrodes are connected and impedances are satisfactory, ask the patient to perform the required task for the test. For cVEMP, ask them to turn their head, and for oVEMP, ask them to look up at the target.
2. In the right-hand side of the Feedback Window, look at the activity monitor for the right and left sides. The fields will update as the patient performs the task, setting the calculation for recommended range.
3. Click the **[Apply]** button next to the field you want to set as your acceptance range value. Or click **[Apply Both]** to apply both the min and max values at once. Note that the values in the calculation will be rounded to the nearest whole µV value and inserted into the Acceptance range fields.
4. After the values are applies, you may ask the patient to stop performing the task.

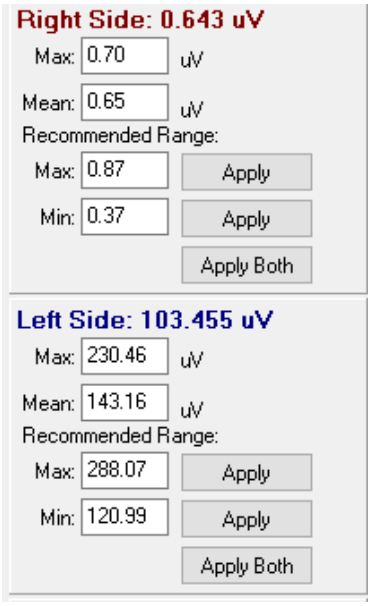


Figure 77 - Detail of EMG Level Feedback window

Keep in mind that the acceptance range values are applied to all channels being acquired. When acquiring in binaural mode, failing to meet the acceptance range on one side will cause the opposite side to be rejected as well.

How the min and max are calculated

The minimum and maximum values are calculated based on the activity recorded while the user is performing the task. The calculations are driven by the selected values for Running average and Percent Range found at the bottom right of the window. The recommended range values are calculated using the following formulas:

$$\text{(Recommended Max)} = \text{(Measured Max)} + \text{(\%Range)}*\text{(Measured Max)}$$

$$\text{(Recommended Min)} = (0.7)*\text{(Measured Max)} - \text{(\%Range)}*\text{(Measured Max)}$$

Patient feedback options

These tools can be used to provide feedback to the patient that there is enough muscle activation while the VEMP recording is in progress. Using the feedback tools will yield more reliable recordings.

VEMP Feedback Box

This hardware accessory is equipped with LED lights, indicating whether the current EMG activation is satisfactory, or out of range.

Figure 78 - VEMP Feedback Box

VEMP EMG Level Feedback window

This window appears automatically when the SmartEP software is set to the VEMP modality. It is recommended to place this window in a secondary monitor or positioned in a way that allows easy viewing by the patient and/or examiner.

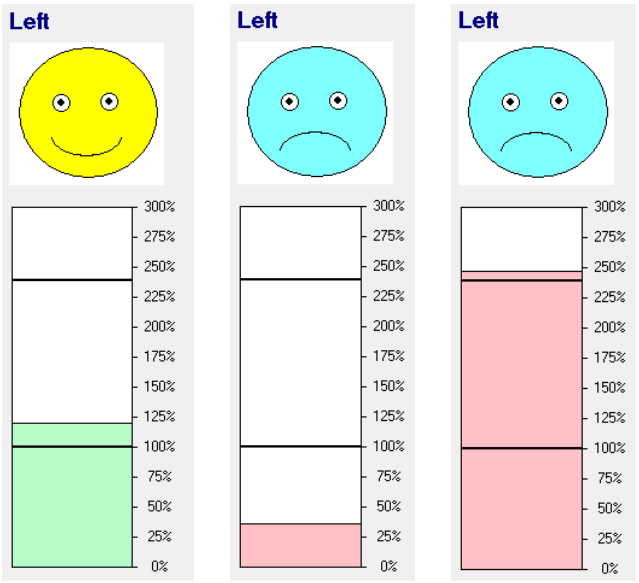


Figure 79 - In activation range (left), Out of range (center and right)

When there is proper EMG activation, the bar level graphic will be colored in green, accompanied by a happy face. If the video option is active, the video will play while satisfactory activation is achieved.

When the EMG activation is outside the range, whether it is below the minimum or above the maximum, the bar level graphic bar will be colored red, accompanied by a sad face. If the video window is active, the video will pause playback while the activation is too low or too high.

Video Feedback window

When the VEMP modality is active, a new option will be visible in the main menu. This option includes functions to add video playback as an aide in keeping proper muscle activation.

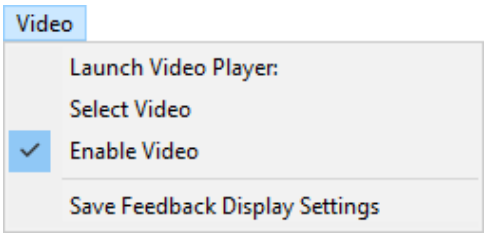


Figure 80 - Video menu

To use the video option:

1. From the main menu choose **[Video > Select Video]**.
2. From the file select option, choose the video file that you wish to use. Note that only MPG, AVI, MP4, WMV, and IFO video file formats are supported. It is also recommended that the videos reside in the Videos directory of the software installation, by default: "C:\IHSPROGS\VIDEOS"
3. When ready, choose **[Video > Launch Video Player]** to open the video window.

The video option will enable automatically when choosing to launch the video player. To deactivate it, simply click the **[Enable Video]** option in the menu to deactivate it.

If the same settings will be used in the future, you may save the selected options by clicking on the **[Save Feedback Display Settings]** button from the menu.

Peak marking and analysis

In order to assess the results of a VEMP acquisition, the waveforms are labeled, then the right and left sides can be compared.

Labeling VEMP responses

VEMP responses are generally marked with the labels N1, P1, and Base. Note that the Base marker is placed automatically by the software in the pre-stimulus region; you may adjust and reposition the base marker as needed. To mark N1 and P1:

1. Select the recording to be marked by clicking directly on it, or on its handle.
2. Right click over the peak or valley where the label is to be placed.
3. Select the **[Mark Peak]** option from the context menu, then choose the label marker from the list.
4. Repeat with other markers to be placed.
5. To have the software measure the peak amplitudes, drag the bottom marker (triangle pointing up) of the P1 label to the position of the N1 label.

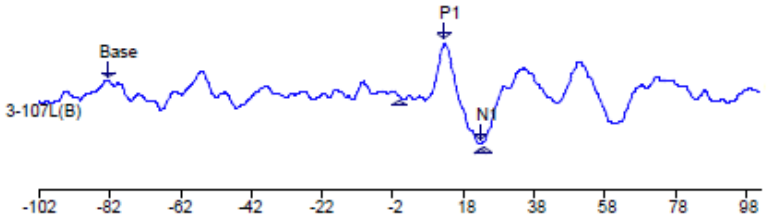


Figure 81 - Sample cVEMP waveform and suggested labeling

Note that for cVEMP waveforms the P1 marker is typically placed before the N1. In oVEMP waveforms, the P1 marker is placed after the N1 marker. The selection of this placement is based on current general usage at the time of this writing.

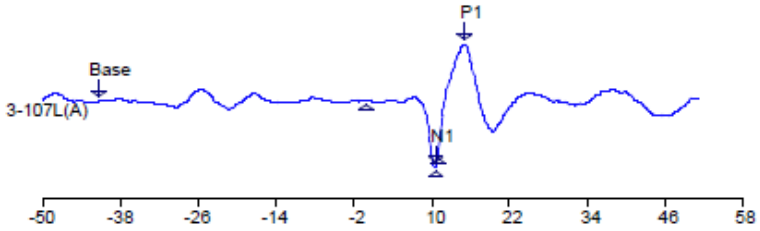


Figure 82 - Sample oVEMP waveform and suggested labeling

Keep in mind that the sample waveforms shown are obtained when using the electrode polarities outlined in the Patient Preparation section. Reversing the polarity of the electrodes will lead to inverted waveforms.

Waveform comparison

After obtaining and labeling the recordings for the Right and Left sides, the sides may be compared. To perform the comparison, select both waveforms by holding down the 'Ctrl' key in the keyboard and clicking on the waveforms with the mouse. Once they are both selected, from the main menu, choose **[Process > Compare Two Selected Recordings]**. The comparison window will appear showing the following information:

- Information for both the right and left ear recordings including file name, Base RMS amplitude, P1 latency, P1 amplitude, P1c corrected amplitude (based on RMS), and N1 latency.
- Asymmetry ratio based on the P1 values for amplitude.
- Asymmetry ratio based on the P1c values for corrected amplitude.
- Latency difference between P1 on the right and P1 on the left.

The information in this window may be copied to the page by clicking **[Yes]** at the bottom of the information window. Choosing **[No]** or clicking **[X]** will close the window.

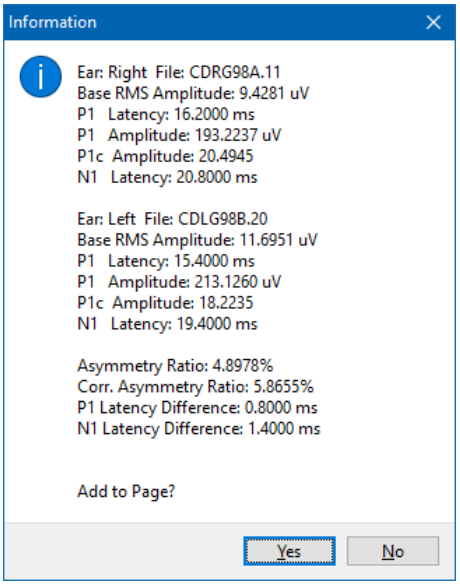


Figure 83 - VEMP waveform comparison

To view this information without opening the process window, select both waveforms, then click the **[Rec Info]** button to the right of the main SmartEP window, then switch to the "Comp" tab.

Somatosensory Modality

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This modality is only available as an add-on for the USB Box hardware platform; it is not available for the USB Jr Duet, USB Jr., Solo, or USBLite. Some consideration must be given to patient safety before starting any type of electrical stimulation protocol.

Electrical Hazard:
When using the Somatosensory equipment, although the intensity of the stimulus resets to 0 by default, the patient MUST BE DISCONNECTED FROM THE STIMULATOR BEFORE POWERING UP. Electrical shock may occur. Maintain the dial on the Stimulator Probe to the lowest position when the equipment is not in use.

Electroneuronography (eNoG)

Electroneuronography testing is performed by stimulating the stylomastoid foramen with electrical stimuli. This procedure will cause a reaction at the nasolabial fold, which can be recorded with the use of electrodes. The process is used to evaluate and measure the integrity of the facial nerve. By comparing the responses from each side of the face, it is possible to determine the amount of degeneration and the best course of action for treatment.

An eNoG recording will contain a small peak corresponding to the masseter muscle, followed by negative peak N1, then positive peak P1 and second negative peak N2; which occur at around 4.5, 7.5 and 12.5 milliseconds, respectively.

Caution:
Consult with the cochlear implant manufacturer if acquiring eNoG on an implanted patient, some manufacturers will have specific requirements for implant safety. The requirements and recommendations of the CI manufacturer supersede the ones given in this manual.

Setting acquisition parameters

Before changing any settings make sure the Somatosensory mode is active, otherwise change the modality to Somatosensory by choosing **[Protocol > Modality > Somatosensory > Standard]** from the SmartEP main menu. Make sure the patient is not connected when changing modalities.

- **Stimulus**: Monophasic or Biphasic pulse of 200 microseconds in duration.
- **Limit**: 40 mA.
- **Intensity**: 15 to 25 mA.
- **Rate**: 1.1 per second.
- **Phase**: Positive.
- **Transducer**: Electrical Stimulation Electrodes.
- **Side**: Unaffected side first, then affected side.
- **Filters**: 1 Hz to 5000 Hz.
- **Notch Filter**: OFF.
- **Gain**: 5k.
- **Analysis Time Window**: 20 milliseconds. To look at the pre-stimulus baseline, change the options in the **[Set Page]** menu.
- **Sweeps**: 10 - 20.

To save the acquisition parameters simply click on the **[Save Settings]** button from the control panel and give the settings file a descriptive name. Then click on **[Load Settings]** when these settings need to be used again.

Note that, for safety reasons, the stimulus intensity will be reset to 0 when switching patients.

Electrode placement guidance

Recording Electrodes

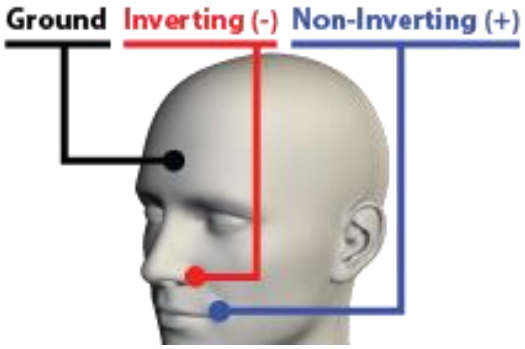

Figure 84 - Electrode positioning for eNoG

- **Red Inverting (-)**: upper nasolabial fold.
- **Blue Non-Inverting (+)**: lower nasolabial fold.
- **Black (⏚)**: Mid-forehead (Fpz).

Electrodes for both sides may be placed before starting the test. For multi-channel Opti-amp transmitters, unused channels should be shorted by placing a Y-Adapter connected to the Red and Blue positions. Merged end can be left unconnected.

Stimulation Electrodes

- Cathode (-): by the mastoid, behind the junction of the jaw and the skull.
- Anode (+): forward from the junction of the jaw and the skull. Keeping at least a one-inch separation between stimulation electrodes.

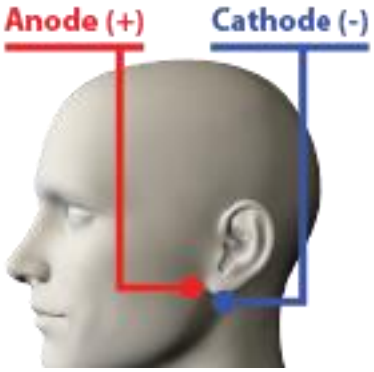

Figure 85 - Guidance for stimulation electrode positioning

Patient state

The patient must be placed in a comfortable environment, where the patient sits upright on a comfortable chair. It is good practice to advise the patient about the stimulation being presented in a sensitive manner, as the electrical stimulation may be unfamiliar and bothersome.

Achieving proper stimulation levels

- Set the Somatosensory probe to its lowest possible setting by rotating the dial before you start. You may place the connectors of the stimulating electrodes on the probe sockets or use the probe prongs.
- If the stimulation electrodes have not been placed yet, use the prongs on the probe by pressing lightly against the stimulus location, starting with the patients' unaffected side. Remember that the surface of

contact of the electrodes is much larger than the surface of the prongs, which will improve the flow of current and causing an amplified reaction.

- The probe prongs are activated by holding the output button. At the same time, rotate the dial, turning the intensity up at least until the patient feels the stimulus. For proper acquisition you will need to raise the stimulus past this point, the stimulus will normally cause discomfort without causing pain.
- Involuntary twitching of the face is normal during electrical stimulation.
- Start testing the unaffected side first. You should achieve a clear response. If the response is not repeatable or has no recognizable structure, the stimulus level may be too low.

Peak labeling

An eNoG recording will contain a small peak corresponding to the Masseter muscle, followed by negative peak N1, then positive peak P1 and negative peak N2; which occur at around 4.5, 7.5 and 12.5 milliseconds, respectively.

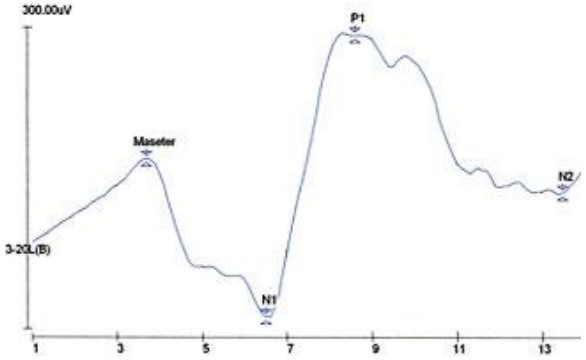

Figure 86 - Sample eNoG waveform.

Comparing waveforms

For eNoG interpretation, the results needed are the differences between the left and right-side recordings. To compare one recording to the other do the following:

- Mark the peaks on the recordings corresponding to each side, one for left, one for right. Remember to drag the bottom marker of the P1 label to the bottom of the next valley, as this will calculate the amplitude of the peak.
- Select one of the recordings, then while holding down the **[Ctrl]** key on the keyboard, select the recording corresponding to the other side.
- Open the side panel by clicking on the **[Rec Info]** button on the right-hand side of the screen, then look at the **[Comp.]** (Compare) tab. The tab contains all the peak, corrected amplitude, and percentage difference information.
- To copy the information to the page, click on the **[Add to Page]** button.

The comparison information is summarized by the percentage difference between one side and the other, this percentage is included in the comparison information. High percentages indicates that the responses are very similar in amplitude, low percentages indicate there is a large difference in amplitude between one and the other. Please consult the appropriate literature for interpretation of results.

Somatosensory evoked potentials (SSEP)

Somatosensory testing is performed by providing surface electrical stimulation to a patient's upper or lower limbs. This procedure is useful to determine the integrity of the somatosensory pathways as well as help diagnose the nature of any possible sensory impairment. A two-pronged handheld stimulator delivers the stimulation to the skin, where pulse stimulation is typically used. Recording electrodes are placed on the limbs being tested and on the subject's skull.

Upper limb electrode placement guidance

Stimulation electrodes

- Anode (+): Inner forearm, one inch (2 to 3 cm) from the wrist.
- Cathode (-): Inner forearm, two inches (5 to 6 cm) from the Anode.

Note the stimulating electrodes do not have a ground electrode.

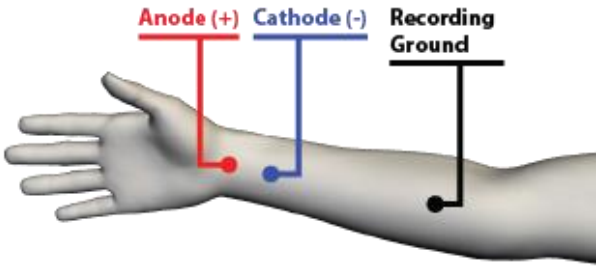

Figure 87 - Stimulation electrode and recording ground positions

Recording electrodes

The following setup uses four channels. To test the right side:

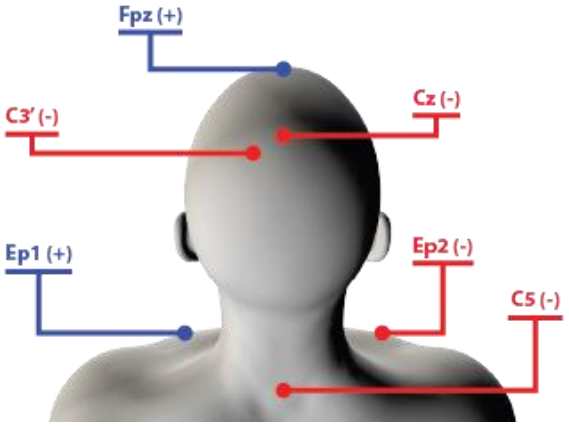

Figure 88- Suggested recording electrode positions, right side.

- **Fpz (+)**: connected to Channel A Blue, non-Inverting, and channel B Blue, non-inverting, using a Y-Adapter. Reference for C3' and C5
- **C3' (-)**: connected to Channel A Red inverting (-).
- **C5**: connected to Channel B Red Inverting (-).
- **EP1, Left Erb Point (+)**: connected to Channel C Blue non-inverting and Channel D Blue non-inverting using a Y Adapter. Reference for EP2 and Cz.
- **EP2, Right Erb Point (-)**: connected to Channel C Red Inverting (-).
- **Cz (-)**: connected to Channel D Red inverting.
- **Ground**: inner forearm, two inches from the elbow fold. Common to all recording electrodes.

To test the left side:

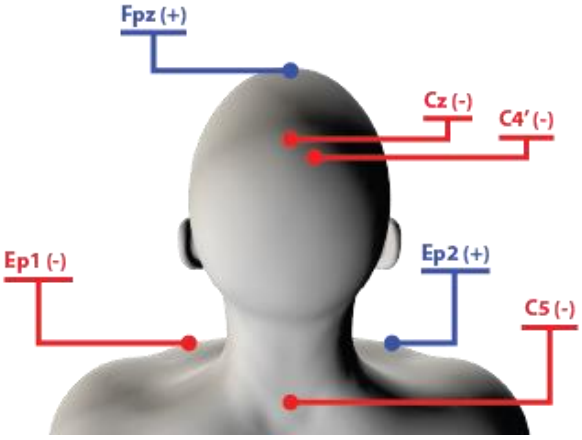

Figure 89 - Suggested recording electrode positions, left side.

- **Fpz (+)**: connected to Channel A Blue, non-Inverting, and channel B Blue, non-inverting, using a Y-Adapter. Reference for C4' and C5
- **C4' (-)**: connected to Channel A Red inverting (-).
- **C5**: connected to Channel B Red Inverting (-).
- **EP1, Left Erb Point (-)**: Connected to Channel C Red Inverting (-).
- **EP2, Right Erb Point (+)**: Connected to Channel C Blue non-inverting and Channel D Blue non-inverting using a Y Adapter. Reference for EP1 and Cz.
- **Cz (-)**: connected to Channel D Red inverting.
- **Ground**: Inner forearm, two inches from the elbow fold. Common to all recording electrodes.

Lower limb electrode placement guidance

Stimulation electrodes

- **Anode (+)**: inner leg, 2" from the ball of the foot.
- **Cathode (-)**: inner leg, 2" to 3" from the Anode.

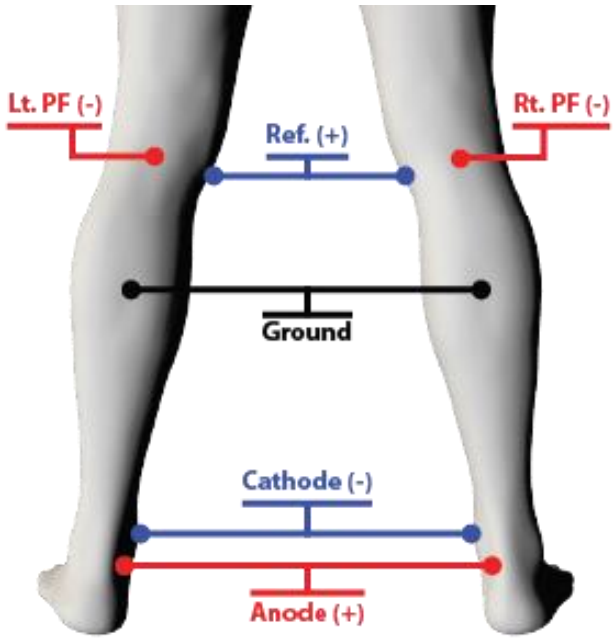

Figure 90 - Stimulation and recording electrode positions.

Recording electrodes

- **Right Popliteal fossa, Lt.PF. (-)**: connected to Channel A Red, inverting, position.
- **Left Popliteal fossa, Lt.PF. (-)**: connected to Channel B Red, inverting, position.
- **Cz', 2 cm behind vertex (-)**: connected to Channel C Red, inverting, position.
- **Lumbar spinal cord, L3 or L5 (-)**: connected to Channel D Red, inverting, position.
- **Inner knee (+)**: connected to Channel A and Channel B Blue, non-inverting, positions, using a Y-Adapter. Reference for Lt.PF and Rt.PF.
- **Fpz (+)**: connected to Channel C and Channel D Blue, non-inverting, positions, using a Y-Adapter. Reference for Lumbar and Cz'
- **Ground**: may be connected to both locations using a linked electrode adaptor.

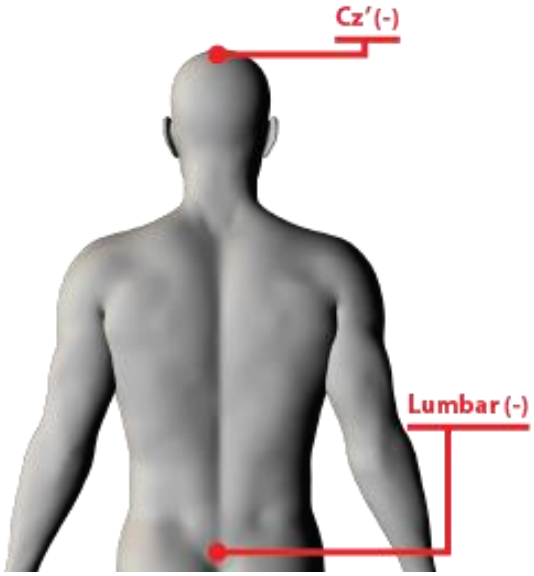

Figure 91 - Cz' and Lumbar electrode positions.

Setting acquisition parameters

Before changing any settings make sure the Somatosensory modality is active, otherwise change the modality by choosing **[Protocol > Modality > Somatosensory > Standard]** from the SmartEP main menu. Make sure the patient is not connected when changing modalities.

- **Stimulus**: Biphasic pulse of 200 microseconds in duration (200 µs Pos, 200 µs zero, 200 µs Neg).
- **Limit**: 20 mA
- **Intensity**: 5 to 15 mA.
- **Rate**: between 3 and 7 per second (5.1 or 5.3).
- **Phase**: Positive.
- **Transducer**: Electrical Stimulation Electrodes.
- **Side**: One then the other.
- **Filters**: 30 Hz to 1000 Hz.
- **Notch Filter**: OFF.
- **Gain**: 50k.
- **Analysis Time Window**: 0 to 30 milliseconds.
- **Sweeps**: 250.

Note that, for safety reasons, the stimulus intensity will be reset to 0 when switching patients.

Patient state

There are no particular requirements for patient state during testing. Responses can be acquired regardless of consciousness level or resting state.

Labeling

To label the recording, select it, then you can use either the standard labels (N1, N2, N3, P1, P2, and P3) found on the toolbar; or use the recording right click menu to select labels not listed on the toolbar (ERB, N9, N14, N18, N20, P23).

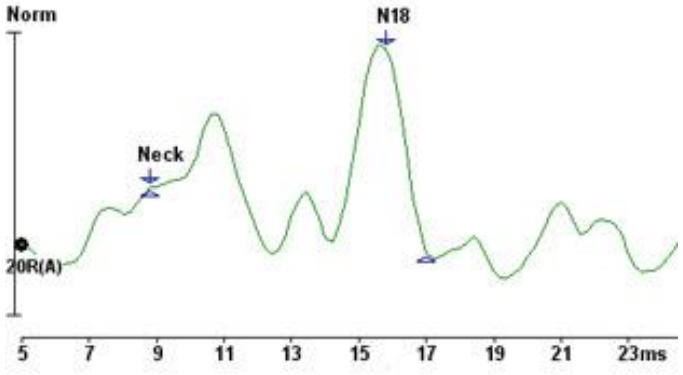

Figure 92 - Sample somatosensory waveform.

Visual Evoked Potentials

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This modality is only available as an add-on for the USB Box hardware platform; it is not available for the USB Jr Duet, USB Jr., Solo, or USBLite.

Patient positioning

Special attention must be paid to patient and equipment positioning during VEP acquisition. The required distance from the visual stimulator to the patient's eye is given by a set formula. In the case of the IHS VEP stimulator, the required distances are:

- 55 to 60 cm. for full field patterns.
- 28 to 31 cm. for half field patterns.

The most common placement is to have the stimulator mounted on a wall or stationary bracket, then place-markers on the floor where the patient's chair should be placed for each case. Alternatively, you may mount the stimulator on a movable arm with set positions, while the patient's chair is stationary.

Patient preparation

Patient status

The patient must be sitting upright on a comfortable chair, while keeping a constant distance to the stimulator panel. Although it may be possible to perform this acquisition while standing, some people may move back and forth while balancing effectively changing the eye-to-stimulator distance. The patient must be fully awake and well rested. Corrective eye wear including glasses and contact lenses must be used if the patient needs them. The opposite eye to the one being tested should be covered with an eye-patch.

Electrodes and locations

Since the recording electrodes are placed on the scalp, Gold Cup electrodes are the easiest to use. Given their smaller footprint they are easier to handle when dealing with hair. Secure the electrode with surgical tape padded with gauze or cotton. The following are the suggested electrode locations:

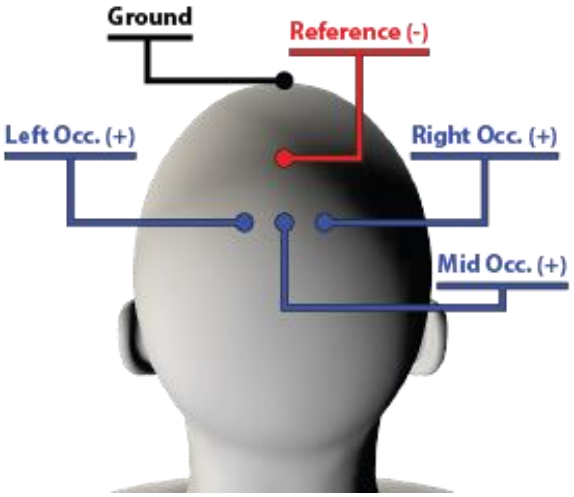

Figure 93 - VEP electrode placement guidance

- **Non-Inverting (+) (Blue)**: One of the following locations
- **Mid-occipital (Oz)**: 2 inches above inion. OR
- **Right-occipital (O2) and Left-occipital (O1)**: 2 inches lateral to Oz.
- **Inverting (-) (Red)**: Central (Cz).
- **Ground**: High Forehead (Fpz).

Testing parameters

Before changing the parameters, make sure to change the modality to VEP by clicking on **[Protocol > Modality > Visual]** from the SmartEP main menu.

- **Stimulus**: Full field or half field reversal checkerboard.
- **Rate**: 1-2 per second.
- **Centering Point**: ON
- **Filters**: 1 to 300 Hz.
- **Notch Filter**: OFF. Turn ON only if there is excessive electrical line noise.
- **Gain**: 100x
- **Analysis Time Window**: 0 to 500 ms.
- **Sweeps**: 100 to 200 for full field, 200 for half field.

Starting acquisition

Before starting acquisition, make sure to instruct the patient to keep their gaze on the centering point, when it is being used. It will be difficult for most patients to avoid blinking during the entire number of sweeps of one acquisition; this may cause either a few rejections, or a few sweeps with no amplitude. Some users may opt to acquire the sweeps in batches, then average them together by using the **[Process > Add Selected Recordings]** option from the SmartEP main menu.

Make sure you are using the correct pattern, verify the rejection level in the Amplifier window, then simply click the **[Acquire]** button to start.

Labeling VEP responses

VEP responses are generally marked with the labels P50, N75, P100, and N145. To mark the VEP responses:

1. Select the recording to be marked by clicking on it, or on its handle.
2. Right click over the peak or valley where the label is to be placed.
3. Select the **[Mark Other Peak]** option from the context menu.
4. Choose the label marker to place it and close the window.
5. Repeat with all other markers to be placed.
6. To have the peak amplitudes calculated automatically, drag the bottom marker of the labels to the next peak or valley.

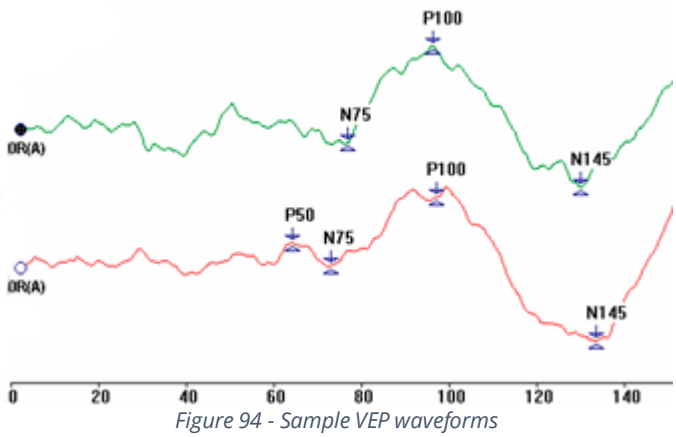

Figure 94 - Sample VEP waveforms

Reference information

The distance formula

For the stimulation pattern to be effective a specific angle of coverage needs to be provided. To meet this angle of coverage, a particular distance needs to be used from the display to the subjects' eye. The required distance is given by the following formula:

$$D = W/(2\mathrm{Tan}(\theta/2))$$

- **D**: is the distance from display to subject.
- **W**: is the total width of the pattern being used.
- **θ**: is the angle of coverage for the total field.

Research Modules

16

All the following modules are meant to be used in research applications and are only available in some hardware platforms. Some of them may involve testing on animal subjects. Due to cross-contamination concerns, never use a hardware unit intended for animal use on human subjects. The use of these modules on human subjects may require you to get government clearance, and/or signed patient release forms. Always follow your country's regulations for documentation and compliance when using these modules on human subjects. Some of these modules may already be approved for clinical use on human subjects in certain locations, contact the IHS offices or your local dealer for details.

Caution:
Hardware units must have a pre-determined intended use when it pertains to the testing subject population. Do not use unit intended for animal use on human subjects, or vice-versa.

High Frequency module

The High Frequency Modality of SmartEP is generally used to assess the effects on hearing from the environment, drugs, and other sources. It is mostly used with animal subjects, although there may be some instances of use in human subjects. The same hardware unit should never be used for both animal research and human subject testing.

Required hardware

Due to the hardware required, the High Frequency Modality is only available on the larger USB Box. The modality will generally require special internal hardware and additional accessories and transducers. Consult your platform's reference documentation for details about connecting these hardware components to your device.

- **ER2 Insert Earphones**: These earphones would replace the use of the standard insert earphones in a situation where sound output needs to reach frequencies up to 12 kHz. These can be used on human subjects. They are also needed when click stimulation is part of the test battery. ER2 Insert Earphones can connect directly to the USB Jr Duet, a Booster Box is required in order to connect them to the USB hardware platform.
- **High Frequency Transducers (HFTs)**: These transducers can be used to provide auditory stimuli of up to 32 kHz. These are meant for use in animal populations only. These transducers are not intended for the output of click stimulus, due to the undesirable frequency composition of the resulting click. When a click stimulus is needed, other stimulators such as insert earphones must be used instead. These stimulators require the use of a Booster Box with high Pass filter to connect to the USB and USB Jr Duet hardware platforms.
- **Booster Box**: This connector box has two variations, one with a High Pass filter switch that can be used with either the ER2 insert earphones, or the HTFs. The second one does not include a filter and should only be used with the ER2 insert earphones only. The purpose of these boxes is to provide the correct electrical energy levels required by the stimulators to output at the higher frequencies. The model with the high-pass-filter switch includes internal circuit to minimize low frequency harmonic distortions when testing at higher frequencies (16 kHz and above).

Activating High Frequency mode

To use the High Frequency modality, activate it by selecting **[Protocol > Modality > Auditory High Frequency]** from the main menu. Once active, it will be possible to select the HFTs as transducers and enter higher frequency output values in the Auditory Stimulus Generation window. Notice that due to the higher clock speeds, the sampling rate of the stimulus output and the sampling rate of the recording will be different than in standard auditory mode. The maximum response sampling rate in high Frequency mode is 31.3

microseconds. The stimulus output duration must be given in multiples of 8 microseconds; any other values entered will be rounded up or down to the closest multiple of 8.

General usage tips

- The high frequency mode has the exact same interface as standard ABR mode. Refer to those sections for additional usage instructions.
- If using click and high-frequency tone stimulation during a single session, and since the HFTs do not output clicks, keep both the HFTs and Insert earphones handy and close to the subject for easy switching.
- Remember to set the switch on the Booster Box with High Pass filter to 'Direct' when testing below 16 kHz, or to 'High Pass' when testing at 16 kHz and above. Using the High Pass filter on the Booster Box will prevent the lower frequency harmonics from affecting your recordings.
- When acquiring evoked potentials and otoacoustic emissions from the same subject in a single session, you may use the transducers while connected to the OAE microphone for evoked potentials.

Caution:
The maximum presentation rate that should be used for acquisition when using the high frequency modality is 100 presentations per second.

Calibration and corrections

When using HFTs for animal testing, it may be necessary to use either calibration or correction to adjust the results based on the animal's ear cavity size.

When the HFTs are being used in combination with the 10B+ OAE microphone, the high frequency transducers should be calibrated for use with each species of animal you will be using for your studies. Different species will have unique average ear canal cavity sizes, which will influence the actual sound output due to the differing acoustic characteristics. Refer to the OAE software manual, or the calibration application note for details on how to calibrate when using this combination.

Caution:
When calibrating the high frequency transducers, special attention must be paid to changing both the calibration values and maximum output values as described in the instructions. Failure to change both values before use will result in damage to your equipment.

When using the HFTs alone, it may be beneficial to establish a baseline for comparison by generating a SPL-to-HL table for each type of animal to be tested. Generating these tables may make it easier to compare data across subjects. For details on how to create a HL table for your use, consult the SmartEP High Frequency Add-on manual.

Advanced Auditory Research Module

The Advanced Auditory Research Module allows the creation of highly flexible recording settings. The controls permit the definition of acquisition timelines where the recording region and stimulation events can be freely moved in said timeline. Although not always necessary, the module benefits from the Ipsilateral Masking hardware option in the Universal Smart Box, which allows this module to mix two auditory stimulus signals in a single ear.

Activating the Advanced Auditory Research Module

To activate the module, simply choose **[Protocol > Modality > Auditory - Advanced Research Module]** from the SmartEP main menu. After switching, the buttons in the control panel will change. The stimulus, stimulation side, phase, and artifact rejection region are now chosen in the setup window found by clicking the **[Setup Advanced]** button. Note that the Artifact Rejection Level, Gain, High Pass filter, and Low Pass filter are still controlled from the Amplifier Settings window.

Example setup

The following is an example setup for the Advanced Auditory Research module. This example is only for demonstration purposes, and it is not intended to show any practical significance.

- The total time for the timeline graph (upper part of the screen), can be found at the bottom right-hand corner of the graph. This value is calculated by referencing the selected acquisition rate, which can be entered on the field by the same name (right hand side of the screen). In this case, an acquisition rate of 19.1 per second allows for a maximum timeline of 52.36 milliseconds in length (or 1/19.1).
- Stimulus presentations are shown as pink and light blue bars. In this case there are two signals on the right ear, one for the activated "Right Ear - Channel 1", and one for the activated "Left Ear - Channel 1". Channel 2 of both sides are inactive.

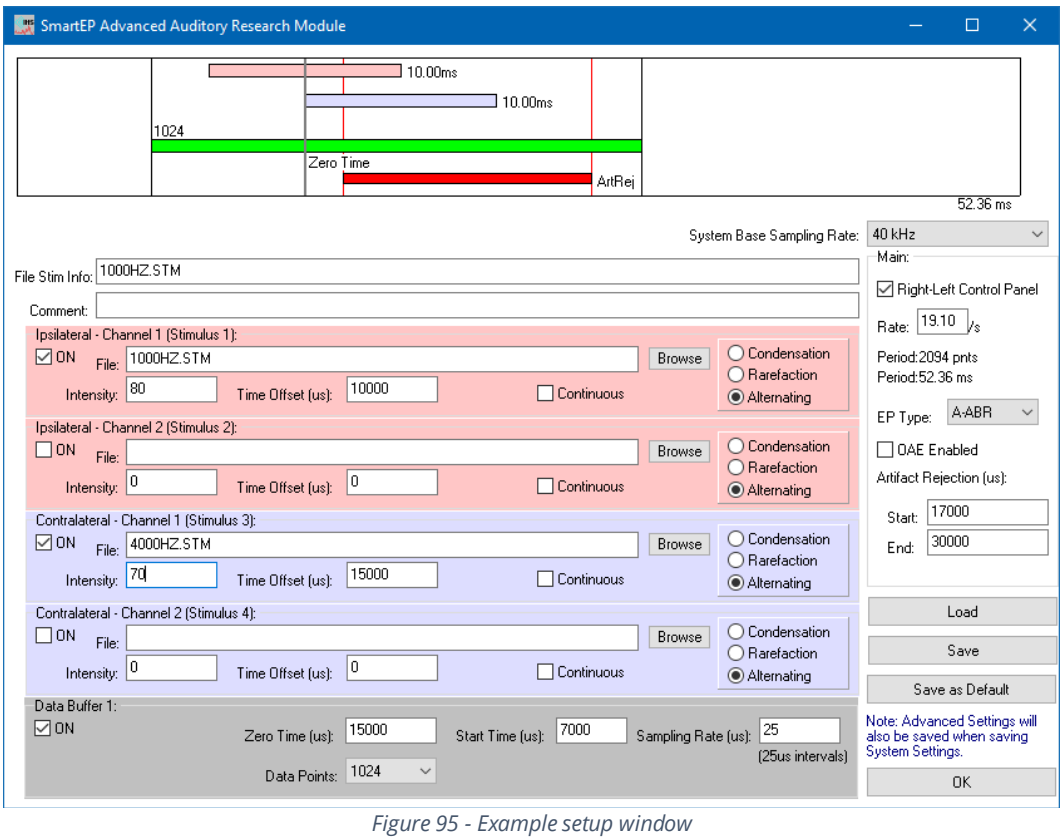

Figure 95 - Example setup window

- Stimulus files are chosen by clicking on the **[Browse]** button to the right of the 'File' field. Stimulus files must have been previously saved, and calibrated, to the "Stim_EP" folder.
- The stimulus file for "Right Ear - Channel 1" has been given a delay of 10 milliseconds, which in this case happens to be a little before the end of the stimulus in left channel 1, making the left stimulus start before the right is finished. Note that if the ipsilateral masking option is not available, only the Channel 1 for left and right could be used.
- The stimulus on "Left Ear - Channel 1" is different file than the one in the right ear.
- When choosing to present a stimulus continuously, it is presented in condensation polarity, 'alternating' is not available as an option when presenting continuously. If using a stimulus continuously, make sure the start and end of the stimulus match well, generally by starting and ending at 0 level, or the stimulus will generate a cracking sound when looped.
- The recording is set to start at 7 ms after the start of the timeline, just before the right ear stimulus. However, the Zero Time is defined to be at 15 ms. This will make the first 8 ms of recording to be in the negative time scale, or the pre-stimulus.
- The length of the recording is calculated by the number of data points and the sampling rate. In this case with a sampling rate of 25 µs and 1024 data points, the total recording time is 25.6 ms. If there is a need for additional data, double the number of points. If the recording extends beyond the timeline, any data points beyond the timeline will be zeroed when the acquisition is executed.
- Artifact rejection will only happen during the time defined by the rejection start and end times as defined in this window. In this example the rejection time is shown as a red bar. The rejection level needs to be set as in standard ABR mode in the "Amplifier Settings" window. To allow all sweeps, set the start and end times to 0, or open the rejection level to 100%.
- In this case the 'EP Type' is set to ABR. This means the software will treat the recorded data as an ABR, making only marked-peak calculation that apply to that type of waveform, like inter-peak latencies. Use the correct of recording type if you need specific calculations such as SP/AP ratios. See Saving as a different data type on page 73 if you need to change the recording type after acquisition.
- For setups where the stimulus needs to be swapped between the Right and Left ears, it may be advantageous to check the box labeled "Right-Left Control Panel." When the box is checked, the **[Ear]** button of the control panel will become active, allowing for switching of the ears without the need to open the setup window again.

Saving settings for the Advanced Auditory Research module

There are two independent sets of parameters used for the Advanced Module, the stimulation and acquisition parameters from the setup window and the acquisition parameters from the control panel. To save your settings for future use:

1. Open the Setup window
2. With all fields already set to the correct values, click on the **[Save]** button to save these settings. Give the file a descriptive name that reflects the setting used. Clicking on **[Save as Default]** will save the settings to a file which will load any time the modality is changed to Advanced Auditory. The Advanced Auditory settings files have a ".ADV" extension.
3. Close the Setup window by clicking **[OK]**.
4. Click **[Save Settings]** from the control panel to save the acquisition settings. Give the file a descriptive name that reflects the settings used.

Note that settings for the advanced module are saved automatically when saving setting from the SmartEP control panel.

Loading settings for the Advanced Auditory Research module

To load settings for the Advanced Module:

- Click on the **[Load Settings]** button from the control panel and choose the Advanced Module settings file. Loading these files will change the acquisition modality automatically.

- Click on the **[Setup Advanced]** button and verify the stimulation settings loaded correctly.
- If the settings are not correct, from the Setup window click on the **[Load]** button and choose the correct stimulation settings file from the list.
- Close the window by clicking **[OK]** and start the acquisition using the **[Acquire]** button.

Peak marking

Peak marking recordings acquired using the Advanced Auditory Research module works the same way as with any other modalities. Refer to Waveform Identification

There are multiple ways to recognize the modality and parameters that were used to acquire a recording, including the text indicators at the start of the plot and the color of the plotted waveform.

The indicators at the start of the waveform include multiple data markers. The stimulus information and acquisition rate can be shown or hidden using the options in the main menu under **[Show > Show Recording Label]**. The first line, includes the following information:

- The intensity of the stimulus in dbs. The number will show the nominal value whether the stimulus was presented in HL or SPL.
- The channel of acquisition in parenthesis; this is also indicated by the color of the plot, typically red for right, blue for left and black for both. Note that the selected waveform will always be a green plot.
- The mode of acquisition, whether it was ipsilateral (Ipsi) or contralateral (Contra). When acquiring from both sides, there will be no indicator, as shown in the third waveform on the right.

The second line of text, the stimulus information will include the following:

- If the stimulation was delivered via air conduction (AC) or bone conduction (BC). If you wish to see the stimulator choice, right click on the waveform, and look at the recording information option.
- The stimulus type, whether it is click, a generated frequency or the name of a loaded STM file.
- When using a generated tone burst (second waveform in the example) the envelope used will be indicated in parenthesis. In case example above, the 500Hz tone was presented using envelope code 7, or Blackman.
- The polarity of presentation, where the options are rarefaction (R), condensation (C), and alternating (A). For waveforms acquired using the Advanced Auditory modality (fourth waveform in the examples) the polarity of each component is shown after the stimulus name. Each digit corresponds to each component's polarity matching the order on the setup window, where 0 is alternating, 1 is rarefaction, 2 is condensation, and 8 means the stimulus component is OFF,

The third line shows the rate of acquisition. If the waveform is tagged as KEEP, using the right-click context menu, the marker will appear as the last line, as shown in the third waveform above.

Any additional information about the waveform acquisition and stimulation settings can be obtained by using the recording information panel located on the right-hand side of the screen. If the panel is not open, click on the **[Rec Info]** button to make it available. Additionally, right-clicking on the waveform will open the context menu, with all the data listed on the file name and information item at the top of the menu.

Placing labels on page 56 for more details. Make sure the recording is the correct type for marking; if needed, the type can be changed using the data menu, if necessary, under **[Recordings > Save File As...]**.

P50 module

The P50 module is only available for the USB Box platform. The P50 module is used to record responses to two equal-length consecutive stimuli, to observe the effect of P50 suppression. These stimuli have two different inter-stimulus intervals (ISI) of separation between them as shown in the graph that follows.

Activating P50

To activate the module, simply choose **[Stimulus > Modality > Auditory - P50]** from the SmartEP main menu. After switching, the buttons in the control panel will change. Most notably, the **[Rate]** button will change to **[ISI]**.

Tips for acquisition

Since the module is a research modality of SmartEP, there is not a full set of suggested settings, but a list of general tips:

- Most commonly, click stimulation is used for acquisition.
- The most used ISI values are 100/500 milliseconds.
- Patient state does not appear to have any effect on the results of P50 suppression. The patient could be sleep or awake.
- Filtering with High Pass set to 1 Hz, Low pass set to 30 Hz or 100 Hz, and gain set to 5 k should be appropriate for acquisition of P50.
- Due to the required long ISI values, it may be beneficial to acquire sweeps in small batches, then add the recordings into a grand average post-acquisition.

Stimulus characteristics

The timeline of the stimulus is shown below. The two inter-stimulus intervals can be defined by entering the millisecond values when clicking on the **[ISI]** button from the control panel.

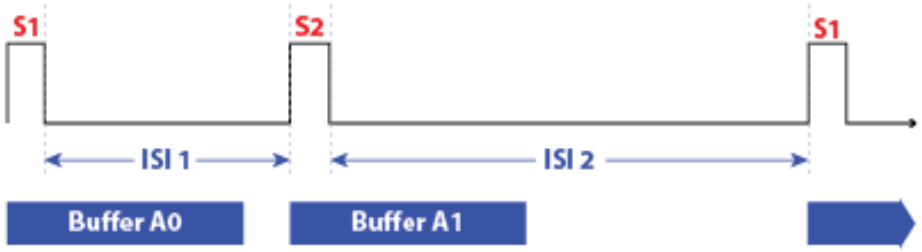

Figure 96 - Stimulus timeline for P50 modality

Electrode locations

The most common location for P50 acquisition is Cz, while using one of the mastoids (A1 or A2) as a reference. The Ground can be placed anywhere, most commonly it is placed on the forehead (Fpz).

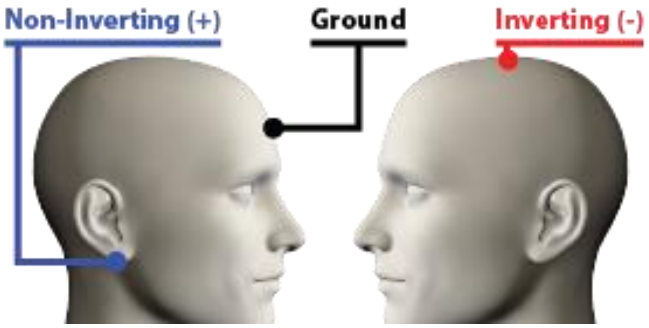

Figure 97 - Suggested electrode setup for P50

CLAD modality

Continuous Loop Averaging Deconvolution is a method of acquiring evoked potentials at very high presentation rates. The resulting waveform needs to be deconvolved after acquisition to obtain a recognizable structure, such as an ABR.

Activating CLAD

To activate the module, simply choose **[Protocol > Modality > Auditory - CLAD]** from the SmartEP main menu, selecting the sub-option for the type of acquisition you wish to record (ECoghG, ABR, MLR or LLR). After switching, a "Open File" window will appear, asking for a choice of CLAD sequence to use. Select the sequence you wish to use and click on **[Open]** to load it. All buttons on the control panel will remain the same as in standard acquisition modes; the only difference is the **[Mod: CLAD Aud]** indicator under the intensity button.

Settings for acquisition

Settings for the acquisition of CLAD are the same as those for the type of response being acquired while in standard mode. Refer to Block Acquisition and Averaging on page 45 for details about acquiring different AEP recordings. The only difference with standard mode is the use of the stimulation sequence. The sequence is selected when the CLAD modality is activated. To change to a different sequence, go to **[CLAD > Change Sequence]** from the SmartEP main menu.

Acquiring a waveform

CLAD recordings can be acquired by pressing the **[Acquire]** button in the control panel. It works exactly as in standard auditory modality. The Auto-Deconvolve option in the CLAD menu is activated by default, as there is no need to view the raw recording, just the deconvolved result.

Peak labeling

Waveforms acquired will be auto saved to match the original AEP type selection when the modality was changed to CLAD. As such they will have the same peak markings as the versions acquired on standard mode. See Waveform Identification

There are multiple ways to recognize the modality and parameters that were used to acquire a recording, including the text indicators at the start of the plot and the color of the plotted waveform.

The indicators at the start of the waveform include multiple data markers. The stimulus information and acquisition rate can be shown or hidden using the options in the main menu under **[Show > Show Recording Label]**. The first line, includes the following information:

- The intensity of the stimulus in dbs. The number will show the nominal value whether the stimulus was presented in HL or SPL.
- The channel of acquisition in parenthesis; this is also indicated by the color of the plot, typically red for right, blue for left and black for both. Note that the selected waveform will always be a green plot.
- The mode of acquisition, whether it was ipsilateral (Ipsi) or contralateral (Contra). When acquiring from both sides, there will be no indicator, as shown in the third waveform on the right.

The second line of text, the stimulus information will include the following:

- If the stimulation was delivered via air conduction (AC) or bone conduction (BC). If you wish to see the stimulator choice, right click on the waveform, and look at the recording information option.
- The stimulus type, whether it is click, a generated frequency or the name of a loaded STM file.
- When using a generated tone burst (second waveform in the example) the envelope used will be indicated in parenthesis. In case example above, the 500Hz tone was presented using envelope code 7, or Blackman.
- The polarity of presentation, where the options are rarefaction (R), condensation (C), and alternating (A). For waveforms acquired using the Advanced Auditory modality (fourth waveform in the examples) the polarity of each component is shown after the stimulus name. Each digit corresponds to each

component's polarity matching the order on the setup window, where 0 is alternating, 1 is rarefaction, 2 is condensation, and 8 means the stimulus component is OFF,

The third line shows the rate of acquisition. If the waveform is tagged as KEEP, using the right-click context menu, the marker will appear as the last line, as shown in the third waveform above.

Any additional information about the waveform acquisition and stimulation settings can be obtained by using the recording information panel located on the right-hand side of the screen. If the panel is not open, click on the **[Rec Info]** button to make it available. Additionally, right-clicking on the waveform will open the context menu, with all the data listed on the file name and information item at the top of the menu.

Placing labels on page 56 for details.

The CLAD sequence

For easier understanding, here is a graphical comparison of the CLAD stimulus trains to Steady State and Transient stimulus.

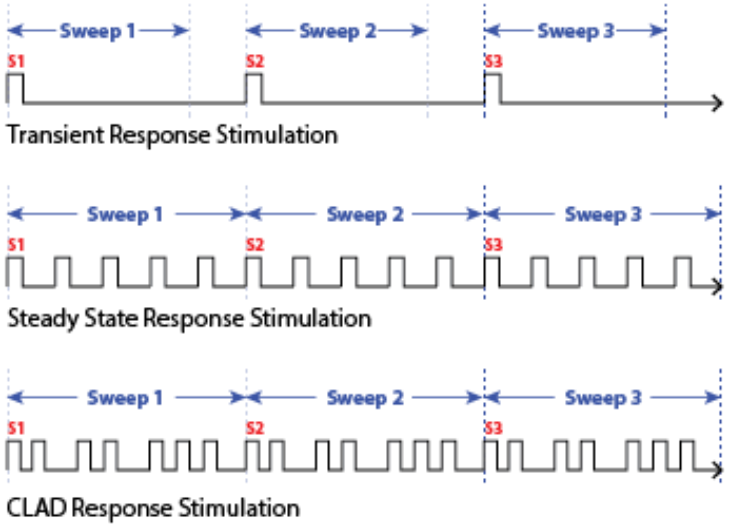

Figure 98 - CLAD sequence compared to Steady State and Standard Transient stimulus trains

- While the transient response stimulation train leaves a gap between one sweep and the next: the ASSR and the CLAD response trains loop around at the specified rate, without gaps.
- The Steady State response has a stimulus train that evenly spaces the stimuli over a single sweep, where the response acquired is looking for synchrony to the stimulus rather than any recognizable structure (as it is the case for the transient responses). On the other hand, the CLAD stimulus train is more like a pattern, where the gaps in the stimuli allow for the extraction (deconvolution) of the transient response.

Creating a CLAD sequence

1. In the software installation folder, "C:/IHSPROGS" by default, find and run the program called "CladGEN.exe"; if your settings are set to not show known extensions then the name will only be "CladGen".
2. In the 'N' field, enter the total number of positions possible for the individual stimulus occurrences. For example, a value of 50 would mean that there are a possible 50 equal stimulus positions during the CLAD loop.
3. Enter the points manually; type them in one per line, into the right-hand side field. Points should never be fully consecutive or evenly spaced as this will hinder the solving algorithm. Sequences of '4, 8, 12, 16' or '1, 2, 3, 4' may never be solvable; Sequences of '4, 8, 12, 15' or '1, 2, 3, 5' have a much better chance of being usable. Values in this column should never exceed the value of 'N' entered in the previous step, and gaps must be left in the sequence. As you enter the points in the column, the information panel to the right of it will show the frequency distribution of the points entered.
4. Click on **[Show Sequence Matrix]** if you wish to see the matrix being used for the calculation. This step can be skipped.
5. Click on **[Invert Matrix]** to find out if the equation is solvable. An indicator under the 'N' filed will inform of the results of the matrix inversion, advising if the equation can be used. If the equation cannot be solved, some small adjustments to the sequence may fix the problem.

6. Click on the **[Simulate]** button to run a full simulation using a waveform, then a convolved waveform and its resulting deconvolved output will be shown at the bottom of the window. A result of simulation will be shown in the info panel, indicating a percentage error, an initial and final level, and a residual level.
7. Once the sequence is finished and it works properly in the simulation, click on **[Save Sequence]** at the bottom right of the window and give the sequence file a relevant name. All sequence files need to be saved in the 'CLADSeq' folder inside the programs installation directory. Sequence files have the extension ".CLAD".

Low Current stimulation

The Low Current Stimulation mode is a research module to use electrical stimulation, usually using needle electrodes, to animal subjects. This module is only available for the USB Box platform.

Activating Low Current modality

To activate the module, simply choose **[Protocol > Modality > Somatosensory > Low Current]** from the SmartEP main menu. After switching, a few of the buttons on the control panel will change.

- The **[Intensity]** button now lists micro amperes.
- The **[Phase]** button now lists options for Positive, Negative, or Alternating.
- A **[Stim]** button allows turning the stimulus output ON and OFF.
- The **[Limit]** button permits setting a maximum output limit for the **[Intensity]** button, to prevent accidental intensity changes beyond usual levels.
- The **[Side]** button allows for change in acquisition between right and left channels, as defined in the Amplifier window.

Electrical Hazard:
When using the Somatosensory equipment, although the intensity of the stimulus resets to 0 by default, the patient MUST BE DISCONNECTED FROM THE STIMULATOR BEFORE POWERING UP. Electrical shock may occur. Maintain the dial on the Stimulator Probe to the lowest position when the equipment is not in use.

Choosing a stimulus

The software comes with a pre-defined stimulus, using the most common stimulus configuration. To view or change the default stimulus, click on **[Stimulus > Stimulus File]** from the SmartEP main menu. To choose a new stimulus file, simply click on the **[Load]** button and select the correct file, then click OK to confirm the selection. It is also possible to create a new stimulus using the Electrical Stimulus Generation window:

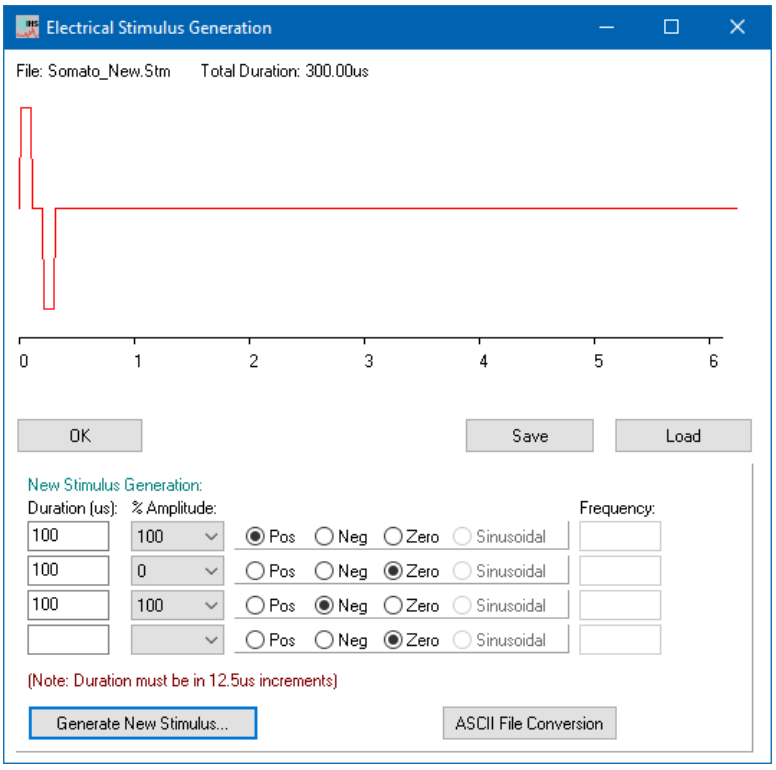

Figure 99 - Electrical Stimulus Generation window

1. Enter duration for the components of the stimulus you wish to create. Duration values must be entered in increments of 12.5 microseconds. Other values will be rounded up or down to the nearest multiple.
2. Choose the relative amplitude percentage for each of the components being used. A value of 100% will apply the full Intensity amount as selected in the Control Panel.
3. For each component, choose whether it is positive, negative, or zero.
4. Click the **[Generate New Stimulus]** button to apply the values entered.
5. Click on the **[Save]** button to store the newly generated stimulus to a file.
6. Click **[OK]** to confirm the stimulus choice.

Test subject preparation

Generally, sub-dermal needle electrodes are used for stimulation and recording on animal subjects. Needle electrodes should be discarded or sterilized after each use. Make sure to follow all cross-contamination prevention procedures for each subject.

Acquiring recordings

Recordings are simply acquired by clicking on the **[Acquire]** button on the control panel. It operates the same way as for performing standard ABR tests.

Peak labeling

Waveforms acquired can be marked using any of the standard markings available to the software or using custom labels. Right click on the recording and select [Mark Other Peak] from the context menu to choose the peak label to place. See Waveform Identification

There are multiple ways to recognize the modality and parameters that were used to acquire a recording, including the text indicators at the start of the plot and the color of the plotted waveform.

The indicators at the start of the waveform include multiple data markers. The stimulus information and acquisition rate can be shown or hidden using the options in the main menu under **[Show > Show Recording Label]**. The first line, includes the following information:

- The intensity of the stimulus in dbs. The number will show the nominal value whether the stimulus was presented in HL or SPL.
- The channel of acquisition in parenthesis; this is also indicated by the color of the plot, typically red for right, blue for left and black for both. Note that the selected waveform will always be a green plot.
- The mode of acquisition, whether it was ipsilateral (Ipsi) or contralateral (Contra). When acquiring from both sides, there will be no indicator, as shown in the third waveform on the right.

The second line of text, the stimulus information will include the following:

- If the stimulation was delivered via air conduction (AC) or bone conduction (BC). If you wish to see the stimulator choice, right click on the waveform, and look at the recording information option.
- The stimulus type, whether it is click, a generated frequency or the name of a loaded STM file.
- When using a generated tone burst (second waveform in the example) the envelope used will be indicated in parenthesis. In case example above, the 500Hz tone was presented using envelope code 7, or Blackman.
- The polarity of presentation, where the options are rarefaction (R), condensation (C), and alternating (A). For waveforms acquired using the Advanced Auditory modality (fourth waveform in the examples) the polarity of each component is shown after the stimulus name. Each digit corresponds to each component's polarity matching the order on the setup window, where 0 is alternating, 1 is rarefaction, 2 is condensation, and 8 means the stimulus component is OFF,

The third line shows the rate of acquisition. If the waveform is tagged as KEEP, using the right-click context menu, the marker will appear as the last line, as shown in the third waveform above.

Any additional information about the waveform acquisition and stimulation settings can be obtained by using the recording information panel located on the right-hand side of the screen. If the panel is not open, click on the **[Rec Info]** button to make it available. Additionally, right-clicking on the waveform will open the context menu, with all the data listed on the file name and information item at the top of the menu.

Placing labels on page 56 for additional details.

VEP for animal research

This Visual Evoked Potential module provides with a flash stimulus using an LED stimulator. This module is only available for the USB Box platform.

Activating VEP for animal research

1. To activate the module, simply choose **[Protocol > Modality > Visual - Animal]** from the SmartEP main menu. When activating the modality, some of the buttons in the control panel will change:
2. The **[Intensity]** button allows the control of the voltage provided to the stimulator in dB V.
3. The **[Stim]** button will change to the **[Duration]** button. With this setting, it is possible to define the length of time the LED will be lit.
4. The **[Phase]** button will not be available as there is no need for this setting.
5. The **[Mod]** button will read "VEPAnimal" to show the current modality.

Test Subject preparation

Generally, sub-dermal needle electrodes are used for recording from animal subjects. Needle electrodes should be discarded or sterilized after each use. Make sure to follow all cross-contamination prevention procedures for each subject.

Acquiring recordings

Recordings are simply acquired by clicking on the **[Acquire]** button on the control panel. It operates the same way as for performing standard ABR tests.

Peak labeling

Waveforms acquired can be marked using any of the standard markings available to the software or using custom labels. Right click on the recording and select [Mark Other Peak] from the context menu to choose the peak label to place. See Waveform Identification

There are multiple ways to recognize the modality and parameters that were used to acquire a recording, including the text indicators at the start of the plot and the color of the plotted waveform.

The indicators at the start of the waveform include multiple data markers. The stimulus information and acquisition rate can be shown or hidden using the options in the main menu under **[Show > Show Recording Label]**. The first line, includes the following information:

- The intensity of the stimulus in dbs. The number will show the nominal value whether the stimulus was presented in HL or SPL.
- The channel of acquisition in parenthesis; this is also indicated by the color of the plot, typically red for right, blue for left and black for both. Note that the selected waveform will always be a green plot.
- The mode of acquisition, whether it was ipsilateral (Ipsi) or contralateral (Contra). When acquiring from both sides, there will be no indicator, as shown in the third waveform on the right.

The second line of text, the stimulus information will include the following:

- If the stimulation was delivered via air conduction (AC) or bone conduction (BC). If you wish to see the stimulator choice, right click on the waveform, and look at the recording information option.
- The stimulus type, whether it is click, a generated frequency or the name of a loaded STM file.
- When using a generated tone burst (second waveform in the example) the envelope used will be indicated in parenthesis. In case example above, the 500Hz tone was presented using envelope code 7, or Blackman.
- The polarity of presentation, where the options are rarefaction (R), condensation (C), and alternating (A). For waveforms acquired using the Advanced Auditory modality (fourth waveform in the examples) the polarity of each component is shown after the stimulus name. Each digit corresponds to each

component's polarity matching the order on the setup window, where 0 is alternating, 1 is rarefaction, 2 is condensation, and 8 means the stimulus component is OFF,

The third line shows the rate of acquisition. If the waveform is tagged as KEEP, using the right-click context menu, the marker will appear as the last line, as shown in the third waveform above.

Any additional information about the waveform acquisition and stimulation settings can be obtained by using the recording information panel located on the right-hand side of the screen. If the panel is not open, click on the **[Rec Info]** button to make it available. Additionally, right-clicking on the waveform will open the context menu, with all the data listed on the file name and information item at the top of the menu.

Placing labels on page 56 for additional details.

17 User Interface

Main Menu

Patient

- **New**: Opens the Patient Demographics window to create a new patient file.
- **Edit**: Opens the Patient Demographics window with the information for the current patient file.
- **Open**: Opens the Patient List window.
- **Clear Data on New Patient**: When active, all recording pages will be cleared when a patient file is opened, or a new patient file is created. When inactive, the information will remain in place.
- **Quit**: Closes the SmartEP software.

Protocol

- **Settings**: Shows the currently loaded system settings file. Clicking on this option will open the settings file load window. 'SEPWIN.SET' is the default settings file.
- **Modality**: Shows the current acquisition modality. Click an option in this menu to switch modalities. Items that are grayed-out are not allowed for the current license.
- **Duet Mode**: Use to change the modality of operation between dual channel and single channel. Single channel modes are specific to the type of cable used. The single channel modes are only available for the Auditory modalities.
- **Continuous Acquisition**: When active, the acquisition will restart, using the same settings, after the sweep count is reached. When in this mode, the system will need to be stopped manually.
- **SNR Estimation Region**: Used to define the start and end times for the SNR calculation region. Requires the use of the system password.
- **Residual Noise Auto-Stop Level**: When set to a value other than 0, recordings will stop automatically when its residual noise reaches the entered value.
- **Setup Automated Protocol**: Opens the Setup Protocol window, allowing the creation of a new automated protocol sequence.
- **Execute Automated Protocol**: Opens the Open Protocol window, allowing the selection of a previously saved protocol.

Stimulus

- **Stimulus**: Shows the currently selected stimulus. Opens the Auditory Stimulus Generation window.
- **Masking**: Shows the currently selected masking option. Opens the Auditory Stimulus Generation window.
- **Level Step Size**: Defines the increase/decrease value of right-clicking or left-clicking on the intensity button.

Amplifier

- **Amplifier Settings**: Opens the Amplifier window.
- **Amplifier Blanking Time**: Reduces the gain in the amplifier, from 0 up to the selected time, to prevent amplifier saturation. Only available in eABR modality.
- **Digital Filter**: When active, it applies the filters selected in the Digital Filter Settings options. Digital filters will affect the waveform as it is recorded. These filters cannot be undone post-acquisition.
- **Digital Filter Settings**: Shows the currently selected digital filters. Click on the options to modify the values for high pass and low pass filters.

Recordings

- **Path**: Points to the current patient file folder, the location where the patient files and reports are saved.
- **Load Recordings**: Opens the Load File window with the list of all recorded waveforms.
- **Load Recordings from Protocol Files**: Opens the Load Protocol window. Use to load of all recordings that were acquired using an executed protocol.
- **Save Active Recording**: Saved the currently selected recording.
- **Save All Recordings**: Saves all recordings, on all pages.
- **Save Active Recording as…**: Saves the recording as a different recording type or name.
- **Save Single Sweep Data as…**: This option is only available for some modalities, when the average contains a small number of sweeps. Saves the sweeps of the last acquired recording as individual single sweep recording files.
- **Save as ASCII**: Saves the currently selected recording to an ASCII file, a tab delimited text file.
- **Auto Comment**: Opens a comment field window. The comment entered in the field will be added to all acquired recordings until the field information is changed, or the software is re-started.

Averaging

- **Block Averaging Method**: Used to activate block averaging and select the type of averaging that is used when recording. When OFF, blocks won't be recorded. The options for recording blocks include Standard, Bayesian Weighted, Weighted, Median, and Smart. Only available in some modalities.
- **Block Averaging**: Used to choose a block size. The options are: 2, 10, 20, 50, and 100.
- **Calculation Mode**: Used to define if applying a new calculation method modifies the recording that is currently on the screen or creates a new recording buffer while leaving the original one in place.
- **Calculate Standard Average**: Applies a simple standard average to the blocks of the selected recording and generates a new waveform. All blocks are considered to have equal value. The submenu options offer a choice between applying it to the selected recording, or all block average recordings on the page.
- **Calculate Bayesian Weighted Average**: Applies a Bayesian weighted average to the blocks of the selected recording and generates a new waveform. Blocks with lower variance from the mean will contribute more to the average. The submenu options offer a choice between applying it to the selected recording, or all recordings on the page.
- **Calculate Weighted Average**: Applies a weighted average to the blocks of the selected recording and generates a new waveform. Blocks with lower variance from the mean, and lower residual noise will contribute more to the average. The submenu options offer a choice between applying it to the selected recording, or all recordings on the page.
- **Calculate Median Average**: It will apply a median average to the blocks of the selected recording and generates a new waveform. This average calculates a new average based the median value for each individual data point. The submenu options offer a choice between applying it to the selected recording, or all block average recordings on the page.
- **Calculate Smart Average**: It will apply a Smart Average to the blocks of the selected recording and generate a new waveform. Creates a new average based on a weighted average, where the blocks are filtered based on the Smart Averaging Filter selections. The submenu options offer a choice between applying it to the selected recording, or all block average recordings on the page.
- **Smart Averaging Filter**: The values chosen are used to calculate the Smart Averaging waveforms. Choosing either one of the options will activate the values. When choosing OFF, the Smart Averaging will use open filters, from 0 to 5000 Hz.
- **Fsp Point**:
  - **Select Fsp Point**: Use to enter a value for the fixed single-point used for Fsp calculations.
  - **Select Fsp Point from Active Cursor:** Defines the Fsp point location from the location of the cursor.
  - **Update Active Fsp/Fmp Value**: Used to recalculate the values for Fsp and Fmp when changing the Fsp point from a previous value.

- **Update Fsp/Fmp Value and Display Progress**: It updates the value of the Fsp and Fmp and generates a series of waveforms showing the progression of the acquired blocks. The step size is determined by the value selected in the Block Averaging Analysis Block Size option, found later in the Averaging menu. In addition, it will generate an FStat Analysis file with the progressive values for Sweeps, Signal-to-Noise Ratio, Fsp, Fmp, and Residual Noise; this file is saved to a temporary location in C:\IHSExportData\TEMP, to keep this file, save it to a different location.

- **Block Averaging Analysis Frequency**: This option allows the selection of the frequency to be used for the phasor display analysis.
- **Block Averaging Analysis Block Size**: Determines how the blocks are displayed in the phasor analysis. Selecting any block size greater than 1 will group consecutive blocks into the selected options for display. It also determines the progress step when showing block progress in the Fsp options.
- **Block Averaging Phasor Display**: Activates the display of the block phasor analysis. The analysis is shown below the EEG display on the side panel.
- **Split Blocks (Active)**: Loads all the blocks for the selected recording as individual waveforms on the screen. The averaged waveform will remain on the screen.
- **Export Blocks to ASCII File**: Opens a "save file" window, where the individual block information can be saved to a text file for use in third party applications.

Process

- **Addition/Subtraction Mode**: Use to change the addition or subtraction mode. Microvolt weighted will result in a simple addition/subtraction. Sweep weighted will take into consideration the number of sweeps contained in each recording and add or subtract the waveforms proportionally, resulting in a grand average.
- **Add Selected**: Adds the selected recordings into a new recording. To select multiple recordings, hold down the **[Ctrl]** key while choosing the recordings. The created recording needs to be saved manually.
- **Add**: Adds all the displayed recordings into a new recording.
  - 'All on Page' will add the waveforms normally.
  - 'All on Page with Peak V aligned' will align all peak V markers to the earliest marked by time shifting the recordings, then add them into a new recording. Labels must be placed before using this option.
  - 'All on Page with Peak V Aligned - Mean Latency' will align all peak V markers to the mean latency of the label set by time shifting the recordings, then add them into a new recording. Labels must be placed before using this option.
- **Subtract Two Selected Recordings**: Subtracts one recording from another, putting the result into a new waveform. It performs the operation A minus B, where A is the active recording (dark filled recording handle), and B is the secondary selection (grey filled recording handle).
- **Multiply**: Multiplies the selected waveform amplitude values by a user selected constant.
- **Compare Two Selected Recordings**: Compares recordings and their markers; usually performed on as Left vs Right, or when comparing latency changes based on presentation rate differences. For certain modalities, additional calculations may be provided, such as in VEMP.
- **Invert**: Inverts the active recording µV values. Typically used to correct reversed electrode polarities, or to invert the result of a subtraction.
- **Filter**: Use to set and apply post-acquisition digital filtering
  - 'Filter Type': shows the selected filter type; click to select a filter type and its settings. Available filter types include FIR "Finite Impulse response" (smoothing filter), spectral band pass, and spectral notch.
  - Active Recording: Applies the selected filter and settings to the active recording. It creates a temporary copy of the waveform. To keep the filtered recording copy, it must be saved to a file.
  - All on Page: Applies the selected filer and settings to all recordings on the current page. It creates temporary copies of the waveforms. To keep the filtered recordings, they must be saved to files.
- **Duplicate Active to New Recording**: Creates a temporary copy of the selected recording. To keep the recording copy, it must be saved to a file.

- **Time Shift Active Recording**: Shifts the active recording by the specified amount, entered in 'ms'.
- **Cross Correlate**: Compares recordings over the specified period. The period of cross correlation is defined by the cursors. If cursors are not active, they will be activated by any of these options.
  - 'Two Selected Recordings': shows the cross-correlation value for the two selected recordings.
  - 'Within Active Recording': shows the cross-correlation value for the two internal averages of the active recording.
  - 'Active Recording with All on Page': shows the cross-correlation of the active recording to all other recordings on the page; it generates a text file which opens in the windows-default text editor.
- **Split Active Recording**: It separates the recording internal averages (A and B) into separate tracings. Can be used to split an Alternating phase waveform into a Rarefaction and a Condensation waveform.
- **Spectral Analysis**: The option in this menu shows a power spectrum representation.
  - 'Active Recording': Opens the power spectrum window with analysis for the selected recording.
  - 'All on page': Generates a text file with FFT information for every recording on the page.
  - '2D & 3D by intensity': Opens a window showing a graph where frequency if the X axis, Amplitude is the Z axis, and stimulus intensity is the Y axis; showing the energy distribution as the stimulus intensity changes using multiple possible views.
  - '2D & 3D by sequence': Opens a window showing a graph where frequency if the X axis, Amplitude is the Z axis, and sequence is the Y axis; showing the energy distribution in the order of acquisition using multiple possible views.

ASSR

This menu will only be available if the ASSR software license is active.

- **Analyze Active**: Opens the ASSR analysis window for the selected ASSR recording.
- **Generate ASSR Response Audiogram**: Opens the ASSR Audiogram window for the ASSR recordings on the current page.
- **Extract ABR Components**: Extracts the ABR responses from the selected ASSR recording into new temporary waveforms.

cABR [1]

This menu will only be available if the cABR software license is active. The MATLAB options require installation of MathWorks MATLAB or the Standalone cABR analysis tools.

- **Analyze Selected Recordings**: Opens the cABR Analysis window for the selected recordings. When selecting multiple recordings, the analysis window will create a grand-average.
- **Spectrogram - Active Recording**: Opens the cABR Spectrogram window for the active recording.
- **MATLAB Phaseogram**: Sends the active recording for analysis into the MATLAB Phaseogram program. Refer to the cABR articles for a description of the functions in this window.
- **MATLAB Pitch Analysis**: Sends the active recordings for analysis into the MATLAB Pitch Analysis program. Refer to the cABR articles for a description of the functions in this window.
- **MATLAB User Program**: Sends the active recording for analysis into the user defined program in MATLAB. For this function to work properly, the program must be named 'Remote_Program_1.m' and reside in the 'C:\IHSPROGS\IHS_Matlab_Library' folder.
- **cABR Articles**: Opens a folder containing Articles related to cABR techniques.

Show

- **Acquisition Auto-Arrange by**: Defines if the software will automatically arrange waveforms as they are acquired, and the method used. Selecting 'None' will disable auto-arranging of the responses.

[1] Research supporting this technology was developed by Dr. Nina Kraus and colleagues as Northwestern University. Visit the Auditory Neuroscience Lab website (www.brainvolts.northwestern.edu), directed by Dr. Nina Kraus, for information about the research supporting the cABR technology and about upcoming scientific talks by Dr. Kraus.

- **Normalize During Acquisition:** When active, the waveform being currently acquired will be plotted in Normalized mode, once completed the waveform will set itself to the page scale.
- **Automatically Adjust Size**: When active, it makes the waveform's vertical spacing adjust based on the number of waveforms acquired and the type of auto-arrange currently selected.
- **Show by Intensity**: Arranges the responses automatically by intensity level. Automatically separates the left and the right channels on a split screen layout.
- **Show by Intensity (Overlapping Channels)**: Arranges the responses automatically by intensity level. Overlaps the left and right channels on a full screen layout.
- **Show by Acquisition Order**: Arranges the responses automatically by the order in which they were acquired, from first to last. Separates the left and the right channels on a split screen layout.
- **Show by Stimulus Frequency**: Arranges the recordings automatically by the type of stimulus used. Separates the left and the right channels on a split screen layout.
- **Show by Stimulation Rate**: Arranges the recordings automatically by the rate of stimulation, from high to low. Separates the left and the right channels on a split screen layout.
- **Show Recording Label**
  - 'Stimulus Information': when active, the stimulus type will be shown by the recording handle.
  - 'Rate Information': when active, the stimulation rate will be shown by the recording handle.
- **Show Text next to Label**: These options are used to activate the showing of label latency and amplitude information next to the peak markers.
  - 'Apply to Acquired Data': Shows the label information for all recordings acquired while this option is active.
  - 'Apply to...': The following three options will turn on the display of peak amplitude and latency values next to labels for either "All Data" in all report pages, "All Data on Page" for the current page, or for the currently "Selected Data".
  - 'Remove from...': The following three options will turn off the display of peak amplitude and latency values next to labels for either "All Data" in all report pages, "All Data on Page" for the current page, or for the currently "Selected Data".
- **Show Contralateral Responses:** When recordings are acquired from both ears simultaneously, this option can be used to show or hide the contralateral waveforms from the screen and report.
- **Show Toolbar**: Shows or hides the toolbar.
- **Show Cursors**: Shows or hides the vertical cursors. Cursors are required for cross correlation calculations to provide the time window to be used.
- **Show Baseline**: Shows or hides a horizontal line across the recording, at the calculated baseline value. The baseline value is calculated using the pre-stimulus region.
- **Show Zero-Time Position**: Shows or hides the vertical bar at the zero time on the horizontal time scale. It is useful when the zero position is not shown due to modified plot start and end times.
- **Show Lat-Int Graph**: Opens the Latency-Intensity Graph window. The window uses the peak-marked recordings from the current page to build the graph.

Report

- **Load Report**: Opens the Load File window with a list of previously saved report files.
- **Save Report**: Opens the Save File window to allow the storing of a report file. Saved reports include all recordings and other report items, and their positions on all pages.
- **Save report to PDF File**: Opens a report into a PDF file, this is equivalent to printing all pages to a PDF file.
- **Add**: These options are used to include non-recording information to the pages. Dynamic options will update automatically when the relevant information changes. Static options can be edited manually.
  - 'Text': Opens the text editor, then places the entered text on the page.

- 'Text - Demographic Information (Dynamic)': Opens the text editor, pre-filled with the patient demographics information.
- 'Text - Active Recording Information (Dynamic)': Places the information about the selected recording on the page.
- 'Text - Active Recording Information (Static)': Places the information about the selected recording on the page.
- 'Table (Dynamic)': Places the recording data table onto the page.
- 'Table (Static)': Places the recording data table onto the page.
- 'Label': Opens the text editor, then places the entered text on the page. This text field will only show the first line of text, even if additional text is entered.
- 'Image': Opens the Load File window with the list of Bitmap images contained in the patient folder. These may include audiograms from SmartEP-ASSR, DP-Grams from SmartDPOAE, or audiograms from IntelligentVRA or Smart Audiometer.

- **Clear**: These options remove objects from the page. Unless choosing to delete, items will remain in the patient folder and can be reloaded.
  - 'Selected': Removes the selected recording or report object from the screen.
  - 'Page': Removes all recordings and report objects from the current page.
  - 'All Pages': Removes all recordings and report objects from all report pages.
  - 'Clear & Permanently Delete Active Recording from Disk': Removes the selected report object from the hard disk. This operation cannot be undone; deleted items will no longer be available.

Print

- **Deidentify Printouts**: When active, patient identifying information will be removed from printouts.
- **Print Page**: Sends the current report page to the windows default printer.
- **Print Page PDF Preview**: Saves and opens the current report page as a PDF file.
- **Print All Pages**: Sends all report pages to the windows default printer.
- **Print All Pages PDF Preview**: Saves and opens all report pages as a single PDF file.
- **Line Thickness**: Sets the thickness for the waveforms when printed. '2' is the default value.
- **Black & White**: Changes the printing method from color to black and white. Recommended when using a black and white printer.
- **Automatic Tables**: The data table at the bottom of the page will print when this option is active.
- **Multi-Page Format**: When activated, a single report page may print to multiple sheets of paper if the recordings take too much space. If not active, some information may be truncated.
- **Print Parameters**: When active, acquisition parameters will be included in a table at the bottom of the printed reports.
- **Print Peak Values**: When active, waveform peak labels and their corresponding calculated values will be included in a table at the bottom of the printer reports.
- **Printer Setup**: Opens the windows printer setup window. See your printer documentation for details.

Help

- **Open Manual**: Opens the PDF version of the manual.
- **About**: Opens the software version information window.

Main Screen

Indicator Bar

It is located below the main menu

- Patient Identifier: The identifier for the currently loaded patient file
- Recording name: File name for the currently selected recording
- Recording values: List the Peak-to-Peak amplitude (**PP**), the Signal-to-Noise Ratio (**SNR**), Residual Noise (**RN**), and multi-point F-ratio (**Fmp**) for the selected waveform. The Fmp value is only available for recordings made with block averaging active.
- Amplitude and Time: provide the current recording amplitude and time position of the mouse pointer for the selected waveform.
- The current page number and page description appear to the right.

Quick Access Toolbar

It is located under the indicator bar. It contains shortcuts to some of the most used menu items.

- **New Patient:** Opens the Patient Demographics window so a new patient folder can be created.
- **Load Patient:** Opens the Patient List, so an existing patient folder can be loaded.
- Peak label marker buttons: They change depending on the type of recording selected.
- **Load EP File:** Opens the Data Files window.
- **Save EP File:** Saves the currently selected recording.
- **Save All EP Files:** Saves all the recordings on the page.
- **Full Page/Split Page Toggle:** Toggles between Split-Page and Full-Page views.
- **Filter Active:** Applies the currently selected post-acquisition filter, see **[Process]** in the main menu.
- **Arrange by Intensity:** Arranges the waveforms on the current page by stimulus intensity.
- **Arrange by Acquisition Order:** Arranges the waveforms on the current page by order of acquisition.
- **Arrange by Stimulus Frequency:** Arranges the waveforms on the current page by stimulus frequency.
- **Show Lat-Int Graph:** Opens the Latency-Intensity Graph window.
- **Show/Hide Cursors:** Shows or Hides the cursors.
- **Add Text:** Opens the text editor, then places the entered text on the page.
- **Load Report:** Opens the load window with a list of available reports for the patient.
- **Save report:** Opens a save window to save the current page arrangement as a report.
- **Print Page:** Prints the page to the currently selected printer.
- **Print All Pages:** Prints all pages with data to the currently selected printer.
- **Print Page to PDF:** Prints the page to and electronic PDF document.
- **Print All Pages to PDF:** Prints all pages with data to and electronic PDF document.
- **Clear Page:** Clears all objects in the current page. Clearing does not delete the data from disk. Recordings or objects marked as KEEP will remain in place when using this function.
- **Clear All Pages:** Clears all objects from all ten pages. Clearing does not delete the data from disk. Recordings or objects marked as KEEP will remain in place when using this function.

Set Page Menu

It can be opened using the button of the same name, or by right-clicking on one of the page buttons. It contains options for modifying the way recordings are displayed; these settings will not modify the recordings, only the way they are shown. Settings for each page are independent; however, they can be copied to all pages.

- **Page**: indicates which page is being displayed.
- **Page Label**: Shows the button description. Click to change the button and page descriptions.
- **Scale**: Defines whether the recordings are scaled to a defined µV value, normalized, or normalized to the page. Normalized scales the recordings individually by expanding their vertical scale to fit the allowed Plot Size. Normalized-Page finds the recording with the largest peak-to-peak value and scales all recordings on the page relative to that value.
- **Scaling**: Defines if recording normalization is done over the entire display window (plot-start to plot-end) or within a defined time (scaling-start to scaling-end). Only applicable when normalizing.
- **Scaling Start**: Defines start point for normalization, only applicable when recordings are shown normalized, and scaling is set to Special.
- **Scaling End**: Defines end point for normalization, only applicable when recordings are shown normalized, and scaling is set to Special.
- **Page Mode**: Used to switch between full-page and split-page modes. In Split page mode, the screen is divided, typically showing left-ear recordings on the left and right-ear recordings on the right.
- **Move Mode**: Sets the way recordings can be vertically moved on the page. When set to Free, recordings can be placed at any vertical position. When set to Fixed, the recordings will snap to predetermined vertical positions. The number of available positions varies based on the Plot Size setting.
- **Plot Size**: Defines how much vertical space a recording can occupy.
- **Plot Start Time**: Defines the start of the horizontal time scale.
- **Plot End Time**: Defines the end of the horizontal time scale.
- **Plot Time: Right = Left**: Only appears when the 'Page Mode' is set to 'Split'. When active, the start and end time of the display will apply to both the left and the right side of the page. If inactive, the left and right start and end times may be selected individually.
- **Grid**: Toggles the display of vertical grid lines. Lines will appear at each of the entries on the X-axis.
- **Apply above to**: Applies the settings above to the selected page.
- **Clear all data on this page**: Removes all objects from the page. They will remain in the patient folder.
- **Send all data on this page to**: Sends all objects to the selected page.
- **Load Page Labels and Attributes**: Opens a window to load a PLS file containing all display settings for pages 1 – 9. Loading page attributes will modify the display of recordings already on the page.
- **Save Page Labels and Attributes**: Opens a window to save a PLS file with all page labels and display parameters for pages 1 – 9.
- **Save Page Labels & Attributes as Defaults**: Saves the current page labels and display parameters for pages 1 - 9 to the default PLS file (DEFAULT.PLS), they are automatically loaded when SmartEP is opened.
- **Close**: Closes the menu.

Recording Information Panel

Open by pressing the **[Rec Info]** button to the right of the screen. It contains information about the selected recording. A different recording can be selected using the drop-down menu at the bottom of the panel. It contains the following tabs:

General

It shows general information about the recording and patient: Date (when the active recording was acquired), Time (when the active recording was acquired), Patient Age at time of the Recording, Corrected Age at the time of the recording, Comment for the recording. If this recording was the result of a Process operation, the comment will include the name of the original recording and the operation that was performed.

Stimulus

Shows details about the stimulation used for acquisition, including Ear, Intensity, Mode, Rate, Stimulus, Masking level per side.

Recording

Shows additional details about the recording, including sampling rate, number of sweeps, number of artifacts, averaging mode, amplifier gain, amplifier low pass and high pass, line filter status, and digital filter status.

Peaks

If any peaks are marked on the active recording, the labels and locations in latency and amplitude are shown on this table. Pertinent ratio calculations may also be shown in this tab, if applicable.

Response (Resp.)

Shows information about the response including the signal to noise ratio (SNR), single point F-ratio (Fsp), multi-point F-ratio (Fmp), D-Prime value, residual noise (RN), self-cross-correlation, and the noise calculation region, as applicable. The noise values can be updated using the values entered in the field or based on the current cursor positions.

Display

This tab contains display options to change the way the recording is shown on the screen and in printouts. It includes options to show/hide peak labels and printed parameters. It contains an option to show the response as Average (standard), split-sweep (showing both internal averages individually), Plus-Minus (subtraction of the internal averages), or spectral (FFT).

It also includes options to show the recording information directly on the page placing text next to the labels, besides the response, or below the response. The area measurement for ECochG waveforms can also be activated or deactivated from this tab by toggling the corresponding check box.

Comparison (Comp.)

Shows comparison information between two recordings. Comparison information will only be generated when the recordings have been acquired using the same settings. Clicking the **[Add to Page]** button will copy the comparison to a new text field on the page.

Context Menu

The context menu appears when right-clicking over the active object. The options will change based on object type selected.

Recording

- **Recording File Name**: Opens a secondary menu panel that shows information about the recording settings and patient details at the time of acquisition.
- **Peak Latency**: Opens a secondary menu panel that shows information about the marked peak labels including latencies, amplitudes, inter-peak latencies, and other applicable calculation.
- **Mark Peak**: Shows a sub-menu with peak labels that apply to the active recording. When clicked, the label will be placed at the time position where the mouse pointer was at the time the menu was opened.

- **Mark Other Peak**: Opens the Peak Marking window. The chosen label will be placed at the time position where the mouse pointer was at the time the menu was opened.
- **Remove Peak**: The "Specific Peak" option clears the label closest to the time position of the mouse pointer at the time the menu was opened. The "All Peaks" option clears all labels from the recording.
- **Plot Type**: It changes the way the recording is displayed:
  - 'Average': standard average of all sweeps, shown as a single waveform.
  - 'Split Sweep': shows the two internal averages of the recording as two overlapping averages. Used to evaluate individual waveform repeatability or to view the cochlear microphonic.
  - 'Split Sweep – Time Domain Only': Only available for TEOAE responses. It shows the two internal averages, and hides the FFT graph, Meatal Response and Data Table.
  - 'Plus-Minus': shows the difference between the internal averages. Used to evaluate the level of noise of a waveform.
  - 'Spectral': shows the waveform in the frequency domain (FFT). The waveform is split into two curves, one for the repeatable energy, and one for the non-repeatable energy (noise).
- **Keep on Page**: When active, the waveform will ignore general move operations, i.e., it will remain on the page when choosing one of the options to move all data on this page to another.
- **Show Labels**: This sub-menu has options for hiding/showing the labels on a recording.
- **Show Text**: This submenu has four possible options to control the visibility of recording information:
  - 'Next to Label' shows the amplitude and latency information next to the peak labels.
  - 'Side' shows recording and peak label information in a text field to the side of the waveform.
  - 'Below' shows recording and peak label information in a text field under the waveform.
  - 'OFF' hides all information, this does not affect peak labels.
- **Print Parameters**: When active, the recording information is included in the data table when printing.
- **ECoghG Area Measurement**: when active, the ECochG waveform will plot the area under the curve based on the peak marker positions. This is a setting for the individual waveform and will only appear when an ECochG waveform is selected.
- **Scaling**: It allows the scaling to be set to 'Display Window', 'Post Stimulus region', or 'Special'. Scaling only works when the page is set to normalized mode. Applies only to the selected recording.
- **Scaling Start**: Used to set the start of the scaling normalization region when scaling is set to 'Special'.
- **Scaling End**: Used to set the end of the scaling normalization region when scaling is set to 'Special'.
- **Color**: Used to change the color of the recording.
- **Send to Page**: Used to move the active recording to the selected report page.
- **Clear**: Clears the active recording. It does not delete the data from disk.
- **Clear All Selected**: Clears all selected recordings, selected report items, and the active recording from the page. It does not delete the data from disk.
- **Clear and Permanently Delete Active Recording from Disk**: This option will ask for confirmation before deleting the recording from disk. This operation cannot be undone.
- **Close**: Closes the menu.

Report text object

- **Send to Page**: Moves the active object to the selected report page.
- **Clear**: Clears the active object.
- **Clear All Selected**: This option clears all selected recordings, selected objects, and the active object from the page. It does not delete the data from disk.
- **Edit**: Opens the text editor.
- **Close**: Closes the menu.

Report image object

- **Image**: Allows selecting between transparent and non-transparent. When set to transparent, the white pixels of the bitmap image will be set to transparent.
- **Send to Page**: Moves the active object to the selected report page.
- **Clear**: Clears the active object.
- **Clear All Selected**: This option clears all selected recordings, selected objects, and the active object from the page. It does not delete the data from disk.
- **Close**: Closes the menu.

Control Panel

Buttons in the Control Panel may change based on the selected Acquisition modality.

- **Intensity:** Defines the intensity of the stimulus, in decibels. HL or SPL output scale can be selected in the Auditory Stimulus Generation window. Right or left click to decrease or increase, respectively. The intensity level step size defined in the **[Stimulus]** menu. Double click to enter a specific value. Red and Yellow backgrounds are an indicator of high intensity. Refer to the stimulator specifications, in your platform's reference documentation, for maximum output values.

Warning:
Patient exposure to high intensity stimuli must be limited. Present high intensity stimulus only while acquiring. Prolonged exposure to loud sounds can lead to hearing loss.

- **Ear:** Determines the transducer to be used for auditory stimulus; right, left, or both. Left or right click to cycle through the options.
- **Sweeps:** Determines the number of sweeps to be acquired using the current settings. Left-click to set half the amount, right-click to set double the amount, double-click to specify a value.
- **Rate:** Determines the rate of presentation and acquisition, defined as number of repetitions per second. Left-click to decrease the amount by 10, right-click to increase the amount by 10, and double-click to specify a value. The maximum rate allowed is 1000 per second.
- **Phase:** Determines the phase of the stimulus presentation as Alternating (Altr.), Condensation (Cond.), or Rarefaction (Rare). Left or right click to cycle through the options.
- **Stim:** Shows the current stimulus, click to open the Auditory Stimulus Generation window.
- **Acquire:** Starts acquisition. Changes to **[Stop/Pause]** while acquisition is running.
    - **Stop/Pause:** Pauses the acquisition and opens a window asking if it should stop or continue. The button will change back to **[Acquire]** when acquisition is stopped.
- **Continue:** Averages additional sweeps into an existing recording. The original recording is preserved. Changes to **[Restart]** while acquisition is running.
    - **Restart:** Restarts the acquisition. Changes back to **[Continue]** when acquisition is stopped.
- **Mode:** Determines the designated acquisition side. It can be set to Ipsilateral (Ipsi), Contralateral (Contra), or Both. Left or right click to cycle through the options.
- **Time:** Determines the sampling time for the individual data points of a recording, the post-stimulus recording time is shown in parenthesis. Left-click to halve the time, right-click to double the time, and double-click to specify a value. This value can only be entered in 25 µs increments.
- **Load Settings:** Opens a window to load an existing settings file from the "Settings_EP" folder.
- **Save Settings:** Opens a Save File window. Settings files must be saved to the "Settings_EP" folder.

Chain Stimulus modality

- **Setup Chain:** This button opens the Chain Stimulus Setup window. It replaces the **[Intensity]** button while in the Chain Stimulus acquisition modality.

P300/MMN modality

- **Setup P300:** This button opens the P300 Setup window for P300 or MMN. It replaces the **[Intensity]** button while in the P300 or MMN acquisition modalities.

P50 modality

- **ISI:** This button opens a window where the first and second ISI values can be entered. It replaces the **[Rate]** button while in the P50 acquisition modality.

Advanced Auditory Research modality

- **Setup Advanced:** This button opens the Advanced Auditory Setup window. It replaces the **[Intensity]** button while in any of the Advanced Auditory Research acquisition modalities.

Additional Windows

Auditory Stimulus Generation Window

It can be accessed by choosing **[Stimulus > Stimulus]** from the main menu, or by clicking on the **[Stim]** button on the control panel.

Auditory stimulus type

- **Click**: Sets stimulus output as a square wave of specified duration. The duration can be specified in microseconds, in increments of 25 microseconds.
- **Tone Burst**: Sets stimulus output as a sinusoidal wave of specific frequency and duration. The duration of the tone can be specified in microseconds (for most envelopes) or in number of cycles. Use the envelop options to create a shaped burst.
- **File**: Opens an Open File window to allow the selection of a STM stimulus file. Files can be generated from this window using the **[Save]** button on this window once all desired stimulus characteristics are defined, or they can be created using the Stimulus Conversion Utility.

Warning:
Stimulus files must be calibrated before use. Using uncalibrated stimulus files may lead to misdiagnosis and loud sounds.

Stimulator

Use to change the device used for stimulus output. Changing this option will change the output port of the hardware, and/or the calibration that is applied. Grayed-out items are not available to this hardware unit.

Warning:
Always choose the correct stimulator from the list. Stimulator selection changes the calibration table used. Using the wrong calibration table may lead to misdiagnosis and loud sounds.

Envelopes

Envelopes shape Tones to create Tone Bursts, they apply a mask over the structure of the sinusoid to create a ramping stimulus, each with different characteristics. Most options will have a rise/fall time equal to half of the stimulus duration, as predetermined by their mathematical formulas. The Trapezoidal and the Extended Cosine options can have a Rise/Fall time value entered. The Gaussian envelope option will force the stimulus duration to be specified in cycles.

Stimulus presentation

- **Only While Acquiring**: Only outputs the auditory stimulus while acquisition is occurring. Recommended when testing at high intensities to prevent patient discomfort.
- **Continuous**: Outputs the auditory stimulus constantly. Recommended when testing sleeping patients, usually at low intensities, to prevent startling.

Masking

The intensity of the masking stimulus can be provided in two ways:

- **Specific**: Outputs the masking stimulus at the selected intensity value, in SPL.
- **Tracking**: Outputs the masking stimulus as an offset to the stimulus intensity value, as defined in the control panel, in SPL. Negative values are commonly used with this option, so the masking intensity is below the value of the stimulus intensity.

Masking has two output modes, check the corresponding box to activate.

- **Contralateral**: White noise masking is presented, using the insert earphones, to the side opposite to the stimulus. Requires the selection of an intensity mode and value. The **[SAL]** checkbox will switch the output of masking to the bone conductor, and the stimulus to the insert earphones.
- **Ipsilateral**: masking is presented, using the insert earphones, to same side as the stimulus. The proper software license is required to activate this feature. Requires the selection of an intensity mode and value. Noise may be white or notched at specific frequencies using the **[Freq]** drop-down menu.

Mode

Defines if the intensity selection is in SPL (Sound Pressure Level), or in HL (Hearing Level).

Calibration and correction

Shows the total calibration for the selected stimulation options. If the Mode is set to SPL, it will show only the SPL correction values. If the mode is set to HL, it will show the total calibration values (SPL + HL Conversion). The buttons in that section will open the following.

- **Calibration Table:** Opens the Sound Calibration Table, requires the system password. Available when the stimulus type is set to "Click" or "Tone Burst".
- **SPL-to-HL:** Opens the SPL to HL Conversion Table, requires the system password. Available when the stimulus type is set to "Click" or "Tone Burst".
- **File Calibration:** Opens the Stimulus File Calibration window, requires the system password. Available when the stimulus type is set to "File". The window shows the calibration values for the selected file.

Conversion tools

The **Wave Files]** button opens the Stimulus Conversion Utility. This utility can be used to convert a WAV format sound file to the proprietary STM format file.

Additional buttons

- **OK:** Closes the window, confirms, and applies any changes made.
- **Cancel:** Closes the window, discards any changes made.
- **Load:** Opens an Open File window for the selection of a pre-saved stimulus file.
- **Save:** Opens a Save File window for saving a stimulus file, using the current parameters.
- **Display:** Shows a time domain and a frequency domain representation of the current stimulus.

Amplifier Settings Window

This window can be opened by choosing **[Amplifier > Amplifier Settings]** from the main menu or clicking on the **[Amplifier]** button on the side panel.

EEG graph

Located at the top left of the window, the graph shows the live EEG (in blue) as it is being detected by the amplifier. The time scale is based on the selected **[Time]** setting in the control panel. The microvolt scale is based on the selected 'Gain'.

Rejection level and region

The pink color area pictured in the EEG graph is a representation of the Rejection Level and region. This area can be adjusted using the 'Open-Close Level' slider to the right of the graph, and the Region buttons at the bottom of the graph. The microvolt (μV) level of rejection is dependent on the Gain setting; the rejection value can be seen at the bottom of the channel settings section.

Channel selection

Shows radio buttons for each available EP acquisition channel. Selecting a channel from the list will show the channels settings and assigned recording colors for that channel. All settings and color options are channel independent.

Channel settings

These settings are channel independent. Changes to these values are only applied after clicking **[OK]** to close the window; although they can be changed while acquisition is occurring, changes will not apply until the next time the acquire button is pressed. The following parameters are available:

- **Gain**: Sets the gain applied by the amplifier to the incoming signal. The Gain is the factor by which voltage is increased before it is digitized. All value choices are expressed in thousands (k).
- **High Pass**: Sets the hardware filter to be used as a high pass cutoff, filtering out all frequencies below the selected value. All value choices are given in hertz (Hz).

- **Low Pass**: Sets the hardware filter to be used as a low pass cutoff, filtering out all frequencies above the selected value. All value choices are given in hertz (Hz).
- **Line Filter**: When checked, the power line filter is activated, applying a notch filter at the line frequency (60 or 50 Hz, depending on your country or area).
- **Designation**: This item determines how the acquisition channels behave. When in Dual Channel mode, the available options include Right, Left, ON, and OFF. When in Single Channel mode, the available options include Left-Right and Midline.
- **Electrode Montage**: These fields are used for reference only; they do not affect the recording process. This information with be stored along with the recording information.

EEG Sweeps

Used to save the incoming EEG. This information is intended for Research Use Only. If you wish to use this data, contact IHS for information about the data format so it can be read by your application

- **Auto-Save:** Check the box to save the EEG Sweeps to files automatically, a new file will be created when the number of sweeps selected in the drop-down is reached.
- **Save EEG:** Saves the last block of EEG data to disk and resets the counter.
- **Clear Count**: Reset the counter.

Setup Chain Stimulus Window

Open this window by clicking **[Setup Chain]** from the control panel. It is only available when Chain-Stimuli acquisition modality is activated.

- **Active**: Activate one per required intensity level.
- **Intensity**: Use to enter the intensity level. Intensities will only acquire if they are also active.
- **Stimulation Rate**: these four fields define the mean rate of acquisition for the stimulus chain. To use a constant rate, make the mean, maximum, and minimum the same value.
- **Intensity Presentation**: Defines if the active intensities are presented sequentially (from top to bottom) or randomly.
- **Load:** opens a window to load a previously used setup.
- **Save:** opens a window to save the current setup to a file for later use.
- **OK:** confirms and activates the selections, then closes the window.

Setup P300/MMN Window

Open this window by clicking on **[Setup P300]** from the control panel. It is only available while the software is in P300 or MMN modalities.

- **Active**: Check the boxes to activate each stimulus buffer, up to 4 buffers are available for stimulation.
- **Intensity**: Used to define the intensity level for each stimulus buffer.
- **% Present**: Used to define the number of presentations per buffer. The percentage of presentations for the first buffer is calculated automatically based on the other user-entered values.
- **File:** Opens a file selection window. Stimulus files must be inside the "Stim_EP" folder.
- **Stimulation Ear**: Used to select a specific side for sound output. Choosing 'Default' will cause the software to use the selected ear on the control panel.
- **Acquisition Channels**: Used to define the channels that will be active during acquisition. Inactive channels will not generate recordings even if they are active in the Amplifier window.
- **Stimulus**: Activating the Only While Acquiring checkbox will make sure the stimulus is presented only while the acquisition is in progress.
- **Percent Jitter**: This value will add a timing jitter to the presentation of the stimuli.
- **Special Two Buffer 50-50 Mode:** Use this when a 50% sequential presentation Common-Odd is required. Using a 50% presentation rate without this active will result in random presentation.

- **Reject Common After Odd:** Activate to reject the next Common after an Odd presentation. If using the Special Two Buffer Mode, a Common presentation will be added to the sequence to allow for the rejection of the Common following the Odd (i.e., the sequence will be: Common-Common-Odd).

Advanced Auditory Setup Window

Open this window by clicking on the **[Setup Advanced]** button on the control panel. This window is only available while the software is in Advanced Auditory modality. Settings are automatically saved when saving settings from the Control Panel.

Timeline graph

The top section of the window shows the timeline of events as they are programmed on the parameters below. It is a visual aid for the construction of the testing parameters. The following elements may be displayed:

- Active stimulus channels: pink bars for right ear channels, blue bars for left ear channels.
- Recording data buffer: green bar, may be subdivided if larger buffer sizes are selected.
- Artifact rejection: red bar based on set start and end times. Rejection level is set in the Amplifier window.
- Zero-time position: vertical marker at the selected point in the timeline.

Stimulus Channels

There are four available sound channels, two per stimulation side. Activate them by checking the 'ON' box to the left of each channel. To select the stimulus to be used, click the **[Browse]** button and select a stimulus file. Use the '**Intensity**' field to define the intensity for each audio channel. Enter a '**Time Offset**' if the stimulus should not start at the beginning of the timeline. Check the '**Continuous'** box only if the stimulus will be used constantly.

Data

Use '**Data Points**' drop-down to define the length of the sweeps. Total duration will depend on the value entered in the **'Sampling Rate**' field (Total Duration = Number of Points x Sampling Rate). The start of the acquisition can be defined by filling in the '**Start Time**' field.

System Base Sampling Rate

Allows changing the sampling rate of the system (normally 40 kHz) to a lower value. This allows the use of stimulus files that have a longer duration. Options include 40 kHz, 20, kHz, 10 kHz, and a 5 kHz setting. Note that when changing this setting:

- The selected stimulus sampling rate must match the chosen Base Sampling Rate, failure to do so will result in distorted sound output.
- This setting will affect the 'Sampling Rate' setting in the data buffer section, the minimum interval will reflect the base sampling rate that has been selected.

Main controls

The section labeled as Main contains controls for the rate and artifact rejection.

- **'Right-Left Control Panel**': Checking this box will enable ear button in the main SmartEP control panel, while switching the paradigm in the setup screen from a Right-Left setup to a Ipsi-Contra setup, allowing the stimulation side to be swapped externally to this window.
- **'Rate'**: determines how often the timeline is repeated, it also determines the length of the timeline, as shown on the 'Period' information below (in milliseconds).
- **'Period'**: shows the maximum number of data points that can be acquired using the current settings.
- '**EP Type**': Used to define the type of potential that is being recorded.
- Artifact Rejection '**Start'** and '**End'**: Define when the rejection evaluation occurs. The artifact rejection level needs to be defined in the Amplifier window.
- **Load:** Used to load a previously saved Advanced Auditory Settings (AVD) file.
- **Save:** Used to save an Advanced Auditory settings file. They must be saved in the 'Settings_EP' folder.

- **Save as Default:** Used to save the current settings as default for this module (Default.AVD)
- **OK]** Applies the changes to the parameters and closes the window. It does not save parameters.

Latency-Intensity Graph

This graph plots the information, using the data from the placed labels of the recordings currently on the page. The graph plots Latency (milliseconds) of the peaks vs. Intensity (dB) of the stimulus.

- **Stimulus Side Toggles**: The 'Right', 'Left', and 'Both' check boxes can be used to turn ON and OFF the display of data coming from recordings acquired using that stimulation side.
- **Channel Toggle**: Labeled as 'Channel A', 'Channel B', 'Channel C', and 'Channel D'; these check boxes show and hide the recordings that were acquired using the respective channels.
- **Print Graph:** Sends the graphical plot to the default printer as an image.
- **Print Table:** This button sends the data table at the bottom of the window to the default printer.
- **Save Table:** Saves the table data to a text file to the specified location. To import this file into a spreadsheet, define the delimiter as Tabs and Spaces.
- **Copy Image to Page:** Sends the graphical plot data and places it as a report image object on the current page. It will save a copy of this image to the patient folder.
- **Copy Table to Page:** Sends the table data and places it as a report text object on the current page.
- **Norms:** Opens a special normative data file (with extension ".LTS") to be used as reference. Normative data will be shown as gray areas on the graph.
- **OK:** Closes the window.

Power Spectrum Window

The power spectrum window can be opened from the SmartEP main menu by clicking one of the options in **[Process > Spectral Analysis]** in the main menu.

- **Recording Name**: Shown at the top left of the window for reference.
- **Time Domain Graph**: Shown on the left half of the window; it includes the entire recording, the pre-stimulus region is plotted in Red. The post-stimulus region is plotted in Blue.
- **Frequency Domain Graph**: Shown on the right half of the window; it depicts the resulting FFT as a percentage of power measured in Pico-Volts squared. The Blue region is the post-stimulus region. The Red region is the pre-stimulus region.
- **Start:** The value shows the start of the graph, move the slider to change the value.
- **Width:** The value represents the resolution of the FFT. Move the slider to the right to decrease the resolution, move it to the left to increase it.
- **Frequency Selection:** Shows the current frequency selection used for the Phasor analysis, seen at the bottom right of the screen. Move the slider to change the value
- **dB Plot:** Changes the display scale from '% power' to dB.
- **Block Size:** This option determines how many blocks are grouped for analysis.
- **Signal Standard Dev.:** Shows/hides the standard deviation for the response, shown as concentric green circles.
- **Link Signal-Noise Points:** Shows/hides indicator lines that tie together signal plot points to their corresponding noise plot points.
- **Scan:** A scan runs through the frequency selection options automatically to try and find the highest value of d-prime (d') in the spectrum. Once it runs all possible options it will change the frequency selection to the corresponding value.
- **Print:** Sends the current graphic to the default printer.
- **Save as ASCII:** Opens a window to save a text file with the FFT information.
- **OK:** Closes the window.

Troubleshooting

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Hardware errors

My system is not responding

- Is the power LED of the main hardware box illuminated? If not, check that the switch is in the ON position, the power cable is properly connected, the isolation transformer is connected, and all cables are in good condition. If necessary, disconnect the isolation transformer and connect a different electrical appliance to the outlet to verify that the outlet is in good condition and currently providing power. Note that the Solo and USBLite hardware do not have an ON/OFF switch.
- Is the USB cable connected properly; for USB Box and USB Jr. platforms, is the computer connection and Online LEDs illuminated? Check both ends of the cable for proper connection and the cable itself for any possible damage.
- For the USB Box, Duet, and USB Jr., was the SmartEP program started before the hardware was turned ON? If so, exit the SmartEP program, Turn the device OFF, then back ON and then start the SmartEP program again.
- Is the device listed properly in the Windows Device Manager? Check the hardware installation guide and review the steps on installing the hardware device drivers.
- Was the installation of the software completed properly? Turn the system's Switch to the ON position and run System DSP Test from the System menu on the Launch Pad program. It is important that you do so in that order. If you can only see the General and Driver tabs, then the computer cannot communicate with the USB box. Check the cables and power connections again; retest the system.
- Otherwise, go through the tabs pressing the buttons to perform tests on the system. If an error arises, contact IHS with that information.

The software loses communication with the hardware after a while

Make sure all USB Root hubs, in the windows device manager, are not set to conserve power when the computer goes into idle state. In Windows this can be changed by accessing the properties of each USB Root Hub from the windows device manager. In addition, the power settings for USB Root Hubs can be switched from the advanced power management settings.

If this still occurs, make sure the unit is not overheating (too hot to touch). If it is overheating on its own, discontinue use immediately and contact IHS Technical Support for immediate assistance.

The power LED is blinking

The system must be inspected by IHS Immediately. Turn the system OFF and contact Technical Support for details about shipping the system back to IHS for inspection.

Error "USB Connection not Found" appears at startup

The problem may be that the hardware was not turned ON or connected to the computer before SmartEP was started. SmartEP needs to verify the connection and download programs to the hardware unit before it can run. To fix this problem, close SmartEP, turn ON and/or make sure the hardware is connected, and then restart SmartEP. If this does not solve your problem, there must be something wrong with the USB box or its connections; this can also occur with new installations of the software and the device driver was not installed properly. Follow the steps in the "My USB System is not responding" question to find the problem.

Stimulus output

There is no stimulus from the stimulator

- Check that the stimulator is connected to the correct output of the main hardware box. Also verify the connector does not have any bent pins and it is not broken. Verify that the cable and all other connectors are in good condition.
- Is the selected intensity high enough to be audible? Make sure the output is in the correct scale (SPL Vs. HL), SPL will sound a lot lower than HL.
- Access the Auditory Stimulus Generation dialog box using the **[Stim]** button from the control panel. Verify that the correct stimulator is selected as the stimulator on the right-hand panel. Set the stimulus presentation to continuous so it can be heard while the system is not acquiring.
- If the problem is only present on one of the stimulators and not the other, swap the connectors to test. For example, on an insert earphone, connect the red box to the blue cable and vice versa. This cannot be done on some transducers.
- Verify that the Hardware is ON and working properly by following the steps in "My system is not responding", above.

When changing the intensity, the value goes to zero

Each stimulator type has a built-in calibration table that includes values for maximum and minimum allowed output. If a stimulator has not been calibrated for a particular type of output or will not perform as expected with that type of output, it may have its maximum value set to zero. Such is the case for High Frequency Transducers and click stimulation.

If this is happening while using a ".STM" file, open the file in the Stimulus Calibration Utility and calibrate the output before use. Make sure the maximum value is not set to zero. For details about the stimulus calibration utility, consult the Launch Pad manual.

Stimulus Intensity will not go higher

- Make sure the correct stimulator is selected in the Auditory Stimulus Generation window. Some stimulators have lower output limits than others. Built in factory limits are set to avoid stimulus distortion and clipping.
- Maximums vary from one frequency to another on the same stimulator. The maximum possible output of a click stimulus will be different than the maximum for a 1000 kHz tone.
- If using a saved stimulus file for stimulation, make sure it was calibrated and the maximum set correctly. Be careful if using High Frequency Transducers, since setting too high a maximum for them may damage the stimulator. Setting too high a maximum on other stimulators may cause distortion and clipping or may simply generate output at the physical limits of the stimulator.

Amplifier

The EEG waveform is flat

For the USB Box and USB Jr.:

- Is the transmitter switch in the ON position?
- Is the transmitter box receiving power? Move the switch to one of the impedance test positions and verify that the LEDs light up. If not, verify that the power is properly connected.
- Is the fiber optic cable plugged correctly at both ends?
- Unplug the fiber optic cable from the transmitter. Are the sockets where the cable was connected emitting a red light? If not, contact IHS.
- Is the fiber optic cable kinked or bent? Kinks or bends in the fiber optic cable may cause the inside of the cable to break; this will cause the data to stop flowing from the transmitter. Always store the fiber optic cable in a loose circular manner. To test the internal integrity of the fiber optic cable, reconnect the cable to the transmitter and turn the transmitter on. Disconnect the cable from the receiver and

verify that the red light can be seen at the other end of the cable. If you cannot see any changes, the cable may be broken.

- Is the socket where the fiber optic cable is connected to the system broken? This may cause external lighting to enter the transmission receiver, creating too much noise for the signal to be clear.

For all platforms

- Are the electrodes attached correctly?
- Are the transducer silicon tubes or foam tips occluded? Occlusion may lead to extremely low amplitude responses since there is no response to the stimulus.

The EEG is too noisy

- Check the Amplifier rejection ratio. Press Amplifier in the control panel and move the level slider to read between 15 and 30 microvolts for a standard ABR. The rejection level is displayed in the bottom-right information panel. Do the same for all channels that will be used for acquisition.
- Check the high pass and low pass filters in the Amplifier Dialog Box. Make sure the filters are close to the recommended settings for the type of recording that you wish to acquire.
- Is the transmitter away from other electrical devices? If not, move it away from any electrical machinery that may be causing interference, such as computer monitors or electrical outlets. The Amplifier dialog box should show the signal as close to a flat line as possible when the patient is not connected.
- Are the fiber optic cables kinked or bent? If they are, they may be broken inside and may need to be replaced. To test the internal integrity of the fiber optic cable, reconnect the cable to the transmitter and turn the transmitter on. Disconnect the cable from the receiver and verify that the red light can be seen at the other end of the cable. If you cannot see the light, the cable may be broken. Always store the cable in a loose circular manner.
- Is there a 60 Hz (or 50 Hz, depending on your location) signal artifact? Try turning the Notch filter ON.

Electromagnetic interference (noise)

Intelligent Hearing Systems hardware has been designed to prevent electromagnetic interference with other electrical equipment. However, due to the nature of some of the recordings acquired, it is necessary to take some precautions to avoid interference. Electromagnetic Interference received by the IHS hardware has no physiological effects on the patient being tested. However, the interference could lead to inaccurate recordings, therefore leading to possible misdiagnosis. The existence of electromagnetic interference can be observed by the amount of noise received in the signal. If the noise is too high in SmartEP, you should:

- Move the electrode lead cables away from any possible source of interference.
- Position the leads so that they do not cross other cables, preferably away from the patient's body.
- Make sure the patient and hardware components are not close to electrical outlets or any other electrical equipment, if possible.
- When not using shielded electrode leads, braiding the leads may help reduce the effects.
- Move the amplifier away from any older CRT monitors as they may cause interference.

Other basic things that should be done prior to the patient arriving:

- Make sure all equipment is plugged into an isolation transformer, including the PC and all of its attached peripherals.
- Make sure the isolation transformer is plugged into an outlet with earth ground. In many locations, including hospitals, the earth grounded outlets are marked with a green dot.
- If using a cart with metal parts on it, make sure the cart is grounded using the grounding screw on the isolation transformer. Carts will usually have a screw specifically for this purpose.
- The furniture where the patient will rest should not have metal parts touching the patient or any of the cables attached to the system. Metal furniture should also be grounded, if possible.
- Avoid patient contact with heating pads or cooling pads while acquiring.
- Turn off any non-essential equipment in the immediate area while acquiring, including those that have wireless features.

Waveforms

The ABR shows only one large peak at the end, no structure before it

The ABR is probably affected by a Post-Auricular Muscle (PAM) artifact. These artifacts usually occur when the patient is not positioned properly. In a few patients, this will happen regardless of position. There are two options to make the recordings usable:

- Change the scale from a normalized scale to a set microvolt value. Click on the **[Set Page]** button on the right-hand side of the screen and from the menu that opens select one of the **[Scale]** options.
- Change the scaling of the normalization to end before the PAM occurs. Click on the **[Set Page]** button on the right-hand side of the screen and from the menu, change the **[Scaling]** from "window" to "special", then select the **[Scaling End]** to a value just before the PAM starts.

ABR waveforms don't decrease with intensity

The page is most likely set to be normalized. Normalized waveforms are "zoomed in" to help identify peaks and valleys. To correct this, click on the **[Set Page]** button on the right-hand side of the screen and from the menu that opens select **[Normalized Page]** or a particular microvolt value. The best value to choose depends on the waveforms currently shown. Look at the peak-to-peak value (PP value on the information bar) for the higher intensity recordings and make the Scale value slightly higher. This will prevent clipping of the higher intensity waveforms and re-size the lower intensity ones to a relevant scale.

It is also possible that all the waveforms shown do not contain any relevant data. If all waveforms have PP values lower than 0.4 µV regardless of stimulus intensity, and the recordings are not very repeatable, then it is possible that all recordings contain just EEG activity or noise. In this case, verify all recording electrodes and the stimulus output.

Waveforms are missing

The software is set to automatically auto-save every recording. It is possible to turn this setting OFF; however, it needs to be done manually every time the software is started. When acquiring more waveforms than the application can display, waveforms will be cleared from the screen. Most likely this is the result of acquiring data under the wrong patient, or when a patient file was not yet created. Creating the patient file mid-acquisition will also have the same effect. Although the software warns to enter new patient information when none is loaded, it is the user's responsibility to change the patient file or create a new one in between tests.

- Locate the "C:\IHSData\XX" folder and see if any of the files found in there have a creation date corresponding to the time when the patient was tested. If they do, create the patient in the software, then move the data from the "XX" folder to the newly created patient folder, where the name of the folder is the patient file given identifier.
- Locate the folders for patients that were tested just prior to the one in question. Explore the folder and verify the file creation time stamps to see if they coincide with the time of testing for the patient. If they do, create a new patient file in the software then copy the data into this new folder, where the name of the folder is the patient file given identifier. Load and verify that this is indeed the data corresponding to this patient.

Waveforms are not very repeatable

There are multiple causes for this:

- The waveform amplitude is too low. If there is no response from the patient, or there is a problem with either the recording electrodes or the stimulator; it may be that the information shown is simply noise and not a real waveform. Look at the PP amplitude of the waveform in the indicator bar, while the waveform is selected. If the value is below 0.3 µV, the recording most likely contains only noise. Use the Loopback test procedure to verify the unit is working properly.
- There is too much electrical noise. If the latencies and amplitudes seem to vary in large ranges, there is probably too much noise getting accepted causing variability on the response. Fixes include all the suggestions given in Electromagnetic interference (noise) on page 152.

- Small variability in latency and intensity can be attributed to patient noise (EEG), as it is a normal part of the process. This kind of noise is most likely unavoidable, patients that are not in a relaxed state will show this effect more often. Extended acquisition (more sweeps) will close the gap between one response and another; however, this comes at the cost of time, and it may not be needed at all when evaluating the results.
- If testing over multiple sessions, even in the same session sometimes, ambient noise conditions will change, resulting in variability of the responses. As before, this can only be solved by extending the average.

There is no zero time on the horizontal scale

There are two possibilities:

- When showing the pre-stimulus region, it is possible to choose a value that will make the zero-time position of the scale disappear. To find the zero time, activate the **[Show Zero-Time Position]** option from the **[Show]** menu.
- If the scale starts at a positive number other than zero, it can be set to start at zero again by choosing "0" in the **[Plot Start Time]** option of the **[Set Page]** button.

Peak marking

SP/AP ratio is not being calculated automatically

There are two possible issues:

- The ECochG recording was acquired using a different modality, making the software treat it as a different type. To fix this, re-save the recording as an ECochG by selecting the waveform then choosing **[Recording > Save Active Recording As > ECochG]**.
- The bottom markers of the SP and AP labels were not moved to the position of the base, making their amplitudes zero. Simply move the bottom markers of both labels to the position of the Base, the ratio will now calculate automatically.

The peak label is getting replaced

When the user attempts to place a peak label too close to an existing peak label, the software assumes that the previous label is being replaced. To prevent replacement, place the label in a different location, then drag the top and bottom markers of the label into position.

The peak label is not being placed

- If no peaks are showing at all, it could be that the waveform has been set to hide all peaks. To resolve it, right click on the recording, then from the context menu select **[Show Labels > ON]**
- If the peak was accidentally marked too close to the left of the screen, it may have been placed outside of the display area. Either remove all peaks and place them again, or change the Plot Start Time to view the area where the peak was placed.

The label button on the toolbar is not working

When placing a label using the toolbar, make sure to click the button only once. When active, the label button text will turn red. Place the mouse pointer at the time position where you wish to place the marker then click. There is no need to click directly on the waveform, as the software will pick the current mouse pointer time position as the placement location.

My custom label is not on the list

Custom labels need to be added to the list, then the list needs to be saved. Failing to save the list will cause the label to be missing from it next time the software is started. Labels placed on recordings will remain, even if they are not saved on the list.

I can see latency, but I can't find the amplitude

When a peak marker is placed, there are two markers added, a top arrow pointing down and a bottom triangle pointing up. Latency is calculated based on the position of the top arrow, while amplitude is calculated by the

voltage difference between the top and bottom marker positions. When a label is placed, both markers are placed at the same location, yielding an amplitude of 0. Move the bottom marker to the next peak or valley, as applicable, so that the software can calculate the amplitude.

Printing

The data table is not printing

Automatic tables are turned OFF. Click on **[Print > Automatic Tables]** to reactivate the option.

The data table does not show peak information

The recordings were acquired in the wrong modality. The SmartEP program prints table information based on the recording type; recording with the wrong type will not show the information on the table. To correct this, select the affected recording then click on **[Recording > Save Active Recording As]** and choose the appropriate option from the list. The correction may need to be applied to more than one recording.

Recordings are too light on a black and white printer

Some printers will map colors to light shades of gray when printing a color image, in some cases, they may be too light to see. To fix this click on **[Print > Black & White]** from the SmartEP main menu. With this option active, the program will send a plain black and white image to print instead of a color one, avoiding printing to shades of grey.

Font error appears when printing or saving to PDF

This error occurs when a report item containing text has been brought from another computer, or when a font has been deleted from the system since the filed was generated. To correct, look for text fields on the report pages, select them, edit them by right clicking on their handle and selecting **[Edit]** from the context menu, and change the font to one available on this computer by clicking on the **[Font]** button.

Error messages

The following is a list of possible error messages and how to address them.

Application Not Available

This error can occur when a license file is updated, but the software program is not already included in the existing installation. To fix this, re-run the software installation.

Application Not Initialized by IHS...Running in Demonstration Mode

This error will occur when the program is started by running it externally to the IHS program. Close this window then start the program again by opening it directly or clicking on its corresponding icon at the bottom of the Launch Pad program.

Caution: Check Amplifier Parameters - Some values may not match your system options.

This error may occur when loading a settings file that was created using a different device. Not all devices have the same filter and gain settings. To fix this error, open the settings window by clicking on the **[Amplifier]** button in the control panel, then re-selecting the gain and filter values for all available acquisition channels; after that is done, re-save the settings file, overwriting it.

CAUTION - Disk Space

This caution message appears when the computer is running low on disk space. Hard disk space will need to be cleared or added soon to continue normal operation of the computer.

Data Directory Not Accessible

This error occurs when the data folder (typically "C:\IHSData") or the individual patient folder (located inside the data folder), cannot be found. Verify the computer hard drive to verify the data folder and/or patient folder have not been inadvertently moved. Users not comfortable with browsing the computer hard drive should contact either their information Systems department or IHS support for help finding the folders.

DSP not active

This error occurs when there is a miscommunication with the hardware processor, please contact technical support for instructions on troubleshooting and/or sending the hardware to the factory for repair.

Error: Another IHS DSP dependent application is currently running

Multiple IHS programs that control the hardware cannot be run at the same time. Close the other program, then try again. Rebooting the computer will also force close all other programs and solve this issue.

USB Communication Lost... Please Check Connections

This error occurs when the hardware is disconnected from the computer or when the hardware is turned off, while the program is running. The software will recover from this error on its own when communication with the hardware is re-established. If this error occurs frequently, contact IHS support to troubleshoot the hardware. This error may be also caused by faulty USB ports on the computer, it is recommended to try using a different computer in order to rule out the ports of the computer as the cause of the problem.

Error - EPs must be acquired using the same sampling rate

This error occurs when a processing operation is called from the main menu, and the selected waveforms were acquired using different sampling rates. Most processing is not possible unless the sampling rate is the same; the waveforms will need to be reacquired using a the same exact **[Time]** setting in the control panel.

Error - EPs must be acquired using the same reference starting position

This error occurs when a processing operation is called from the main menu, and the selected waveforms do not start and end at the same time position. Most processing operations are not possible unless the start and end times are the same for the selected waveforms; the waveforms will need to be time shifted using the options in the **[Process]** menu to be set to the same timeline before attempting the process operation again.

Error: Hardware does not support Advanced Auditory Modality

This error occurs when the user attempts to change the modality of the program to Advanced Auditory while using a hardware device that does not support it.

Error reading IHSWIN.SYS file - operating without hardware

This error occurs when the license file for the hardware is missing. To correct this, reinstall the software using your original installation media. It is recommended to check the computer hard drive for failure. If this problem occurs after reinstallation, or you cannot find your original installation media, contact IHS support.

Error Reading File

This error appears when the software cannot load the selected file, or files. The cause of this error can be:

- When loading a report, this error will appear if the files needed for the report are not found. This occurs if the files have been renamed or moved. Note down the name of the file that is missing and investigate the patient's data folder to see if the file has been moved, renamed, or deleted. Overwriting the report or setting the missing file back to the expected location will fix the problem.
- If loading a single file, then the file is corrupted and cannot be read. The file is lost and cannot be recovered, the computer's hard drive should be evaluated for corruption.

Error Reading Settings File

This error will appear when the program cannot open the settings file, either because the file is corrupted, or it contains invalid values for the hardware platform. The settings file must be re-created by overwriting it using the **[Save Settings]** button in the control panel. It is recommended to check the computer's hard drive for corruption if this message appears repeatedly.

Error Reading System File...

This error occurs when the license file for the hardware is present but cannot be read. This could be due to a corrupt license file. To correct this, reinstall the software using your original installation media. It is a good idea to check the computer hard drive for failure. If this problem occurs after reinstallation, or you cannot find your original installation media, contact IHS support.

Error Saving File

This error appears when the software cannot save the file, be it a settings file, demographics file, waveforms, or otherwise. The cause of this error can be:

- The current Windows user does not have permissions to write to the installation folder (usually C:\IHSPROGS) or to the Data folder (usually C:\IHSData). To fix this, the Windows user must be granted Read/Write privileges to the folders in question. Check the installation manual for additional information about this subject.
- The folder where the program saves information has been moved. Make sure the data folder (C:\IHSData) and the patient folder (inside C:\IHSData) have not been moved or renamed.

Error: The settings file corresponds to a module that has not been activated on this hardware.

This error will appear when trying to load a settings file that was saved using a different type of IHS device, which has modules available to it that are not available for this device. You may contact the IHS sales team to inquire whether the modality is available to be added to your hardware unit.

Error: undefined buffers

This error occurs when a processing operation is called from the main menu while no waveforms are selected. Make sure you have selected the correct number of waveforms before choosing the option from the **[Process]** menu.

Incorrect Stimulator Changed to System Default

This message will appear when a settings file is loaded, but the stimulator selected for the settings file is not available on the hardware device. The software will automatically switch to the default stimulator, usually Insert Earphones. To fix this, re-save the settings file with the correct stimulator selected.

USB not Responding... Please Check Connections

This error occurs when the hardware is connected and ON but does not respond to software commands. Close the programs, then turn OFF the hardware (for units that have a power switch) and unplug the USB cable. Connect the USB cable, turn ON the hardware (if applicable), then start the software again.

USB Restart Failed

This error occurs when the hardware does not respond to the restart command from the software. Close the programs, then turn OFF the hardware (for units that have a power switch) and unplug the USB cable. Connect the USB cable, turn ON the hardware (if applicable), then start the software again.

Glossary

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10-20 System: most widely used system for localization of electrode positions on a human scalp (ANSI).

ABR: Auditory Brainstem Response.

Alternating: refers to the Phase setting of SmartEP, where the sounds generating will alternate between a rarefaction and a condensation stimulus.

Amplifier: device that produces, as an output, an enlarged reproduction of its input.

Artifact: distortion of the signal from any source other than the recording location; physiologic to external to the system.

ASSR: Auditory Steady State Response.

Average: value calculated from the sum of individual samples, then divided by the number of samples.

AVI: File format for video files. AVI is a container for an encoded video file, using one of a multitude of available codecs.

Band Pass Filter: combination of a low pass and high pass filters where the cutoff frequency of the low pass is higher than the cutoff frequency of the high pass; allowing the range of frequencies in between them to pass.

Barlett window: see Triangular window (Barlett).

Baseline: status of recorded activity when not engaged in a feedback condition, usually referring to the pre-stimulus region.

Blackman window: Is a type of envelope used to shape tone stimulation into a specific curve. This window type is given by a specific equation and not require a rise or fall time. The slope of the curve has proven to elicit the best responses for some types of evoked potentials.

Calibration: Correction applied to sound output so as to correct any differences between measured output and expected output.

Click: It is a square waveform transient stimulus.

Codec: Codifier-Decodifier. It refers to a translation library that allows a media player to read (decode) a video file that was codified in that format. There are hundreds of available codecs; IHS uses the Windows Media Player 9 Codec.

Common Mode Rejection Ratio (CMMR): measure of amplifier quality.

Condensation: refers to the compression or increase of density of air. A condensation stimulus creates the sound by compression, or positive pressure.

Contralateral: Refers to the opposite side of the one receiving the stimulation.

Cosine Cubed window: It is a type of envelope used to shape tone stimulation into a cosine cubed shaped curve. Rise and fall time are defined by the curve itself. It presents a steeper slope than cosine squared.

Cosine Sqr. (Hann) window: It is a type of envelope used to shape tone stimulation into a cosine squared shaped curve. Rise and fall time are defined by the curve itself. It presents a steeper slope than the cosine window.

Cosine window: It is a type of envelope used to shape tone stimulation into a cosine shaped curve. Rise and fall time are defined by the curve itself.

Cross-correlation: a measure of coherence of a signal to another.

ECochG: Electrocochleography.

EEG: electroencephalograph, refers to electrical activity produced by activity of the brain.

EMG: electromyograph, refers to electric currents produced by muscle activity.

EP: Evoked Potential, evoked activity of the brain to a sensory stimulus.

ERP: Event Related Potential, another term for an evoked potential.

Exact Blackman: Is a type of envelope used to shape tone stimulation into a specific curve. This window type is given by a specific equation and not require a rise or fall time. It has a slightly steeper slope than the Blackman window.

Extended Cosine: Is a type of envelope used to shape tone stimulation into a specific curve. The extended cosine has the same slope shape as the cosine window however it includes a plateau. It requires definition of rise and fall time.

Frequency: the number of cycles or completed alternations per unit time of a wave or oscillation.

FFT: Fast Fourier Transform. Refers to the frequency domain representation of a waveform.

FIR: Finite Impulse Response. Filtering method for extracting frequency information. May be used to smooth recordings.

Gain: a measure of the increase in signal amplitude produced by an amplifier, expressed as the ratio of output to input. For SmartEP, low values should be used for responses with large amplitudes, and high values for responses with minimal amplitudes.

Gaussian: Is a type of envelope used to shape tone stimulation into a specific curve. This window type is given by a specific equation and does not require a specified rise or fall time.

Hardware Serial Number: This serial number identifies the main hardware box. This number must match the software for the hardware to be recognized. Use this number to identify which software belongs to each hardware unit.

Hardware Type Code: This code identifies the type of hardware. For units that can use SmartEP: USB Box (4), USB Jr. (5), USBLite (8).

Harmonic: a single oscillation whose frequency is an integral multiple of the fundamental frequency. For example, 8 kHz is the second harmonic of 4 kHz, it is referred to as the second because it is double that of the original.

Hann window: see Cosine Sqr. (Hann) window.

Hearing Level: Hearing Level. Corrected scale for the definition of pure tone sound stimuli, where the 0 point is the level of human hearing threshold for each specific frequency.

High Pass Filter: type of filter that allows frequencies above its cutoff to remain untouched (pass), while attenuating frequencies below it.

Insert Earphone: Small speakers with an attached sound tube. The sound tube is inserted into the ear canal with the help of an ear tip.

Intensity: for auditory stimulation, it refers to the loudness of the stimulus. Given in decibels. For electrical stimulation, usually refers to the amount of current used.

Ipsilateral: Refers to the same side as the one receiving the stimulation.

ISI: Inter-Stimulus Interval. It is the amount of time between stimulus presentations.

LLR: Late Latency Response.

Loopback test: This is a self-check for the SmartEP system.

Low Pass Filter: type of filter that allows frequencies below its cutoff to remain untouched (pass), while attenuating frequencies above it.

Median Average: average in which the individual data points are analyzed to find the median value, that which divides the higher half of the samples from the lower half. This type of averaging eliminates the effect of high or low spurious data.

Masking: process of obscuring the sensory process, in this case auditory. Usually accomplished by presenting white noise.

MLR: Middle Latency Response.

MPEG: File format for video files.

Normalized: In SmartEP it refers to the functionality which makes waveforms conform to the allotted vertical space, similar to a vertical-only zoom.

Notch Filter: combination of a low pass and high pass filters where the cutoff frequency of the high pass is higher than the cutoff frequency of the low pass; blocking the range of frequencies in between them.

Notched Noise: A sound similar to white noise, except it contains no sound energy at a particular frequency range. Usually defined by the frequency at which the notch centers around.

nHL: Normal Hearing Level. Corrected scale for the definition of transient sound stimuli, where the 0 point is the level of human hearing threshold for the specific stimuli. Correction value will vary with stimulus duration, frequency, and envelope type.

Normal Hearing Level: see “nHL”

OAE: Otoacoustic Emissions.

Passband: a combination of a high pass and low pass filters which allows passing of a band of frequencies.

PDF: Portable Document Format. File format developed by Adobe Inc. Universality of the format makes it easy to share the information and keep electronic records.

Phase: In SmartEP, it refers to the polarity of the stimulation, it could be set to rarefaction, condensation or alternating.

Power Spectrum: Refers to a frequency domain representation of a waveforms.

Pure tone: A constant sound at a particular frequency. When shaped by an envelope, such as a Blackman window, it becomes a Tone Burst.

Rarefaction: Refers to the decompression or decrease in density of air. A rarefaction stimulus creates the sound by decompression, or negative pressure.

Rate: Is the frequency of repetition, or how many times per second an event happens. In SmartEP, it refers to how many sweeps occur in a period of one second.

Rectangular window: gives the stimulus a rectangular shape a fall/rise time of 0.

Rejection Level: microvolt level at which EEG activity will cause the software to reject the sweep.

Rejection Region: period during which the artifact rejection level requirement is in effect.

Report: a collection of waveforms, text elements, and images as arranged on the display pages.

Resolution: refers to the amount of data gathered over a specific period. It relates to the sampling rate, where recordings with higher sampling rates could be referred to as having higher resolution.

Resolution (video): Size of the video file in pixels. Also refers to the width and height of a screen in pixels.

Settings: A compilation of parameters used to define an acquisition, may include display settings defining the way things are shown on the screen.

Smart Average: improves on the weighted average by filtering each block, implementing user-selectable high pass and low pass. Filtered blocks with an RN greater than 3 µV will be excluded from the average.

SN10: Slow Negative response at 10 ms.

Sound Field: Refers to sound stimulation provided in area, over the air, without need for patient coupling.

SPL: Sound Pressure Level. A physical measurement scale of sound intensity.

SPL Meter: Device used to measure sound pressure level at a specific location, or from a device when properly coupled.

Standard Average: most common method for acquisition of evoked potentials. A simple average is taken at each time position for all sweeps.

Stimulus: Refers to the energy, be it sound waves or electrical impulses, used to elicit a synchronous response.

System Serial Number: Unique identifier for an entire IHS system. It refers to software and hardware. Use this number when calling for technical support or ordering parts.

Sweep: It is a single pass or iteration of the acquisition, multiples of these result in an average waveform.

Time: In the SmartEP control panel it refers to the amount of time, in microseconds, between one sample and another. Where a collection of samples (data points) makes a recording.

Tone Burst: short duration tone formed by shaping a constant sound (Pure Tone) and enveloping it using a pre-defined window.

Trapezoidal window: Is a type of envelope used to shape tone stimulation into a trapezoid. Requires the definition of rise and fall time.

Triangular window (Barlett): Is a type of envelope used to shape tone stimulation into a triangle. Rise and Fall time are exactly one-half of the stimulus duration.

Threshold: in audiology, it refers to the level of stimulation at which the last response is detected; no response is detected at lower levels.

USB: Universal Serial Bus. Usually referring to the PC ports with that configuration, or the cables that use such ports. Can also refer to the Universal Smart Box.

WAV: File format for computer sound files. Commonly referred to as Wave format.

Weighted Average: average where individual data sets are assigned more or less significance based on the quality of the sample data. For SmartEP, variance and residual noise are taken into account to assign each block its corresponding significance.

White Noise: A sound lacking repeatable structure, with an energy distribution that spans the entire frequency range.