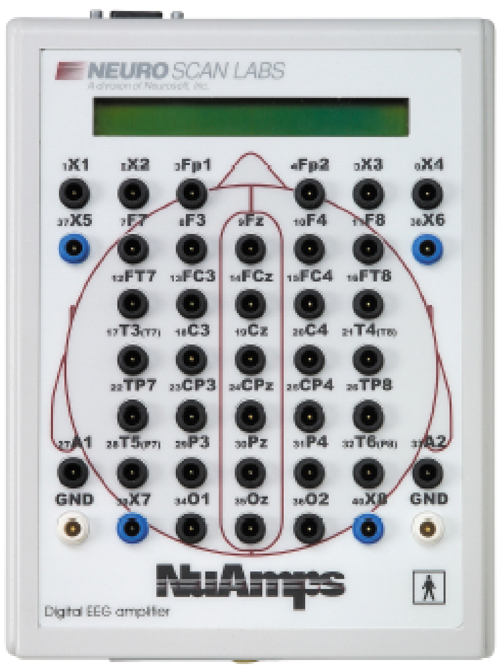
NuAmps 4.4



40 Channel EEG/EP Amplifiers

Table of Contents

1 NuAmps

NuAmps™ User Manual

Compumedics USA, Inc.
6605 West W.T. Harris Blvd., Suite F
Charlotte, NC 28269
USA
Telephone: 877-717-3975 (8am – 5pm EST)

EC REP

Compumedics Germany GmbH
Heussweg 25
20255 Hamburg, Germany
Telephone: +49 40 40 18 99 41
Fax: +49 40 40 18 99 49

Internet: sales@neuroscan.com
techsup@neuroscan.com
www.neuroscan.com

COMPUMEDICS NeuroScan™

1.1 Contact Information

For Technical Support...

If you have any questions or problems, contact Technical Support through any of the following routes.

If you live outside the USA or Canada, and purchased your system through one of our international distributors, please contact the **distributor** first, especially if your system is under warranty.

In all other cases, please use **techsup@neuroscan.com**, or see the other Support options on our web site (*http://www.neuroscan.com*). Or, if you live in the USA or Canada, please call **1-800 474-7875**. International callers should use **877-717-3975**.

For Sales related questions, please contact your local distributor, or contact us at **sales@neuroscan.com**.

7184D NuAmps44

1.2 Device Classification

ATTENTION: CONSULT ACCOMPANYING DOCUMENTS BEFORE USING

The NuAmpsTM Model 7181 amplifiers are a computer-powered instrument designed to meet the applicable requirements of IEC601-1:1988. *NuAmps* should be used only according to the manufacturer's instructions. Replacement parts and accessories may be obtained from the manufacturer.

Manufacturer: **Compumedics Neuroscan USA Ltd.**
6605 West W.T. Harris Blvd., Suite F
Charlotte, NC 28269
Phone: 877-717-3975 (8am – 5pm EST)

E-mail: techsup@neuroscan.com
Web: www.neuroscan.com

This equipment has been tested and found to comply with the limits and requirements for a Class II (portable version) and I (stationary version), Type BF device per EN60601-1-2 and EN55011. These limits and requirements are designed to provide reasonable protection under conditions of normal use from interference with and by other devices. There is, however, no guarantee that interference will not result from operation of this device in proximity or connected to some other device. If interference occurs, the user or operator is encouraged to try and correct the interference by one or more of the following measures:

1) Change the orientation of the two devices relative to one another.
2) Increase the separation between the two devices.
3) Check the power source and grounding for the two devices.
4) Twist amplifier USB cable with photic stimulator serial and power cables
5) Consult the dealer, Compumedics/Neuroscan Technical Support, or an experienced technician for help. A slight degradation of performance may be experienced when the *NuAmps* amplifier is exposed to an RF environment.

The safety and electromagnetic compatibility of this system was tested with the following accessories, parts, and associated devices. The user or operator is cautioned to ensure that when using accessories, parts, or associated devices other than those listed, that the safety and electromagnetic compatibility of the system is maintained.

Portable system:

1) Neuroscan *NuAmps* amplifier, Model 7181
2) Neuroscan *NuAmps* photic stimulator, Model 7097
3) IBM® laptop computer, Model ThinkPad® 390E (CE Marked) or DELL® laptop computer, Model InspironTM 3800 (CE Marked) or other (equivalent and CE Marked) models
4) IPSI 240VAC/15-20VDC medical grade power supply, Model PMP55-13 (CE Marked)
5) AULT 240VAC/5VDC medical grade power supply, Model SW170 (CE Marked)
6) BROTHER® printer, Model MP-21C/CDX (CE Marked) or other (equivalent and CE Marked) models

Stationary (Lab) system:

1) Neuroscan *NuAmps* amplifier, Model 7181
2) Neuroscan *NuAmps* photic stimulator, Model 7097
3) MICRON desktop computer, Model ClientPro® PIII650 (CE Marked) or other (equivalent and CE Marked) models
4) NEC LCD display, Model MultiSync 1525V (CE Marked) or other (equivalent and CE Marked) models
5) Toroid 240VAC isolation power supply
6) HP printer, Model 952C (CE Marked) or other (equivalent and CE Marked) models

Classification per IEC601-1:1988

The device is ordinary equipment not protected against ingress of water and should not be used in the presence of any spilled liquids. It is not designed to be suitable for use in the presence of a flammable anesthetic mixture of air and oxygen or nitrous oxide. The device is capable of continuous operation.

Class and degree of protection against electrical shock is Class II (portable version) or I (stationary version), Type BF.

Technical Description

NuAmps amplifier, Model 7181:

Input:	5VDC	(from USB cable)
Fuses:	None	
Weight:	~1.4 lbs	(695 grams)
Dimensions:	7.8"x5.9"x1.6"	(198x151x40 mm)

NuAmps photic stimulator, Model 7097:

Input:	5VDC	(from AULT power supply)
Fuses:	None	
Weight:	~0.4 lbs	(181 grams)
Dimensions:	4.5"x3.1"x1.3"	(114.3x78.2x31.8 mm)

Shipping and Storage Maximum Limits

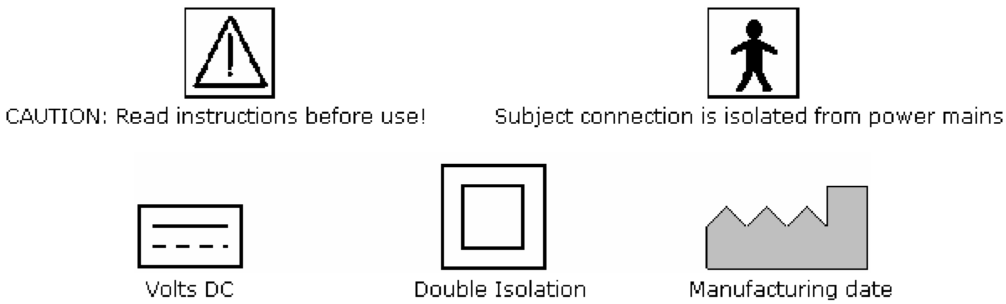
-10° C to + 50° C, 10% to 100% Non-condensing RH, 500 hPa to 1060 hPa. After unpacking, allow devices to adjust to room temperature for at least two hours prior to interconnection and application of power.

Warnings and Precautions

Read instructions before operating the device.

Symbols

The following symbols are found on the *NuAmps* amplifiers:



The *NuAmps* amplifiers contain no user serviceable parts and so are marked “CAUTION: Refer servicing to qualified personnel”.

This device is not equipped with appropriate alarms required for use in monitoring clinical parameters of a patient where it is necessary to alert the user of situations, which could lead to death or severe deterioration of the patient’s state of health.

Manufacturer designs *NuAmps* amplifier Sync1 and Sync2 ports for connection only to Compumedics/Neuroscan approved accessories. Please contact Compumedics/Neuroscan before connecting a device to these ports.

Environment

The *NuAmps* amplifiers are designed for usage in a laboratory or clinical environment. Extremes of humidity, temperature, or pressure should be avoided. The device should not be used in a location where contact with liquids is possible, and if liquids are spilled on or in the area of the device, it should not be used until it can be ensured that the fluid or its residue will not affect device operation. Questions should be directed to the manufacturer or its representatives.

Cleaning Instructions

The *NuAmps* enclosure may be cleaned with a damp sponge or cloth and mild nonabrasive cleanser. Take care to ensure that liquid does not spill in or on the device. Do not use abrasives or detergents.

Sterilization and Cleaning of Patient-Contact Parts

Patient electrodes are supplied as part of the *NuAmps* system. Follow their manufacturer’s instructions for sterilization and cleaning of these parts. Some devices are designed for onetime use only, and no attempt should be made to reuse them, whether sterilization has been attempted or not. Contact Compumedics/Neuroscan Technical Support if you have questions about sterilization or cleaning of the *NuAmps* amplifier or electrodes to be used with the device.

Repair

There are no user serviceable parts neither fuses in the *NuAmps* amplifier, which is indicated on the back panel label as “CAUTION: Refer servicing to qualified personnel”. Contact your dealer or Compumedics/Neuroscan Technical Support if you believe the *NuAmps* system is in need of repair.

Maintenance

Compumedics/Neuroscan suggests that the earth and patient leakage currents be tested at least once per year to ensure continued safe use of the device. Also at least once per year visually inspect the device, including power cord. Replace any worn or frayed cables, and contact your dealer or Compumedics/Neuroscan Technical Support if you have concerns about what you see. This inspection interval may be shortened for devices that are moved often or experience unusually heavy use. No calibration of device is required.

Installation Precaution

Proper grounding is important for continued safe use of your *NuAmps* system. Ensure that the outlet supplying power to your *NuAmps* system is grounded, and that the power cords supplied with your system are used. Other devices in the same patient area should be at the same ground potential, and should preferably use the same branch circuit. See the Hardware and Software Installation directions below for more details.

Power Source Characteristics

The *NuAmps* device is designed, produced, and tested to ensure reliable operation when connected to power systems having normal variability. If you believe that your power system may experience excessive noise or variability, Compumedics/Neuroscan recommends use of a power conditioner.

Interconnection with Other Devices

Care should be taken when multiple devices are connected to a patient, or when devices are connected together. Leakage currents for individual devices may sum to values higher than expected for single devices. In particular care should be taken when connecting Information Technology (computer) equipment to Medical equipment. Allowable leakage current levels for IT equipment are higher than for Medical equipment.

Use With HF Surgical Equipment

This device does not contain protection against burning of the patient when used with high frequency (HF) surgical equipment. Compumedics/Neuroscan recommends that the *NuAmps* device not be connected to the patient during use of HF surgical equipment.

Electrode Safety

The *NuAmps* amplifier inputs and attached electrodes are Type BF, which means in part that they are not connected to Earth Ground or Chassis Ground. Maintain this separation from Earth Ground by ensuring that the electrodes and any conductive parts of their connectors do not touch conductive parts, including the system enclosure or other grounded devices.

1.3 Introduction

The Neuroscan *NuAmps* are DC amplifiers designed to record a wide variety of multichannel neurophysiological signals, such as EEG, ECG, EOG, and EMG. The *NuAmps* are intended for the researcher who needs a small portable amplifier that attaches to any computer with a USB port. *NuAmps* can be used with Windows 2000 and XP.

- Analog inputs: 40 unipolar (bipolar derivations can be computed)
- Sampling frequencies: 125, 250, 500, 1000Hz per channel for all channels
- Sampling method: all channels sampled simultaneously
- A/D resolution: 24 bits
- Full scale input range: ±130mV
- Input impedance: Not less than 80MOhm
- CMRR = 100dB at 60Hz
- Bandwidth: 3dB down from DC to 262Hz, dependent upon sampling frequency selected
- Interface Universal Serial Bus (USB), full support for Plug-and-Play technology
- Supported electrodes (as long as they do not exceed the dynamic range of the amplifiers, which is approximately + /- 100mVs):
  - Gold, Ag/AgCl, Carbon electrodes with Touch Proof (DIN 42-802) style connectors
  - QuikCap Ag/AgCl electrodes with Plastic DSUB37F
  - Tin electrodes (within acceptable saturation range)
  - Sintered silver electrodes
- Digital (TTL) inputs/outputs; 14 inputs and 2 outputs
- Quality control of electrode application
  - Measurement of contact impedance (at frequency 30Hz) in impedance mode
  - Constant monitoring of connection during recording
- Isolation: Optical Signal Isolation
- Display: 16-letter LCD with background light, displaying amplifier status or electrodes with impedance greater than specified cutoff.
- Power supply and energy consumption: From USB (5V), in active mode current ≤ 500mA, in standby mode current ≤20mA
- Electric safety level: According to EN60601-1(type BF), IEC601-1

2 Installing NuAmps

Installation of *NuAmps* software and hardware is very easy. The basic steps are:

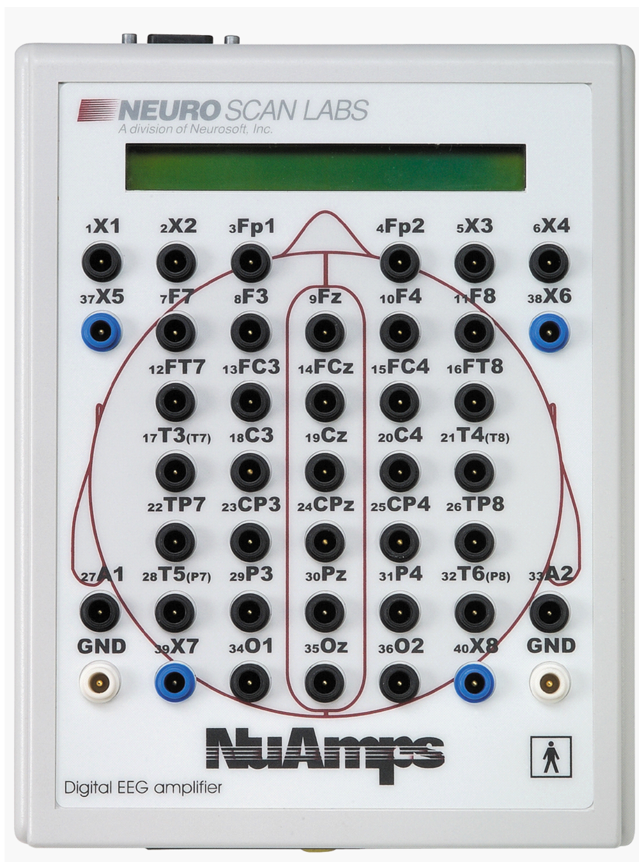
1) Unpack the system components,
2) Connect the isolation transformer (if supplied),

3) Install the SCAN software,
4) Install the *NuAmps* hardware,
5) Configure SCAN for *NuAmps*, and
6) Perform a quick system test.

NOTE: The power supplies MUST be connected to the isolation transformer, if one was sent to you, and that must be plugged into a grounded wall outlet (3-prong). The ground should be a genuine earth ground, and it should be inspected by an electrical engineer.

NOTE: If you received a Photic Stimulator, please refer to the Photic Stimulator manual for installation and operational details.

2.1 1. Unpacking the NuAmps



The *NuAmps* has been shipped in a container designed to reduce damage due to shipping. Please retain this box and its contents in case you need to return the system for any reason.

Open the box and check for the following contents:

1. *NuAmps* amplifier

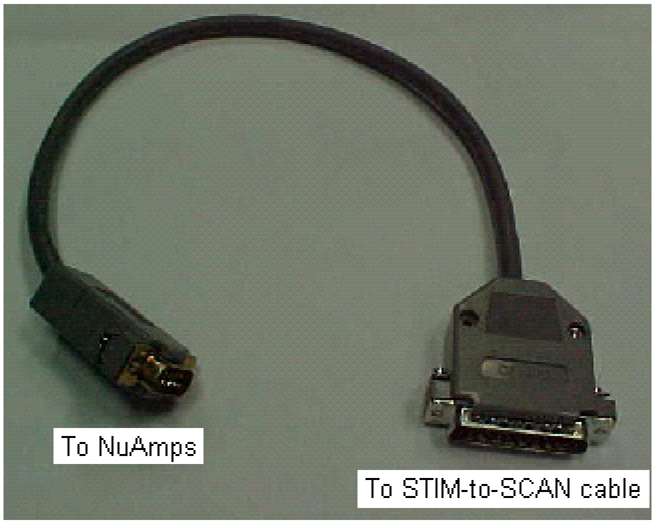
2. 3' or 15' USB cable to connect *NuAmps* to the computer. (The A-type connector goes to the computer; the B-type of connector goes to *NuAmps*).

3. SCAN 4.2 (or newer) CD, if purchased (CD and software key may be shipped separately).

4. Software key, if the SCAN software was purchased (yours may be smaller than the one shown, or a USB type).

5. PocketTrace-2 unit and adapter

6. Adapter cable for the STIM-to-SCAN trigger cable. The 9-pin connector (DSUB9M) connects to *NuAmps*; the 25-pin connector (DSUB25M) connects to the STIM-to-SCAN cable.



Additional options include:

7. Isolation transformer, optional (separate box). If you purchased the laptop computer from Neuroscan, or if you run on batteries, no isolation transformer is needed. Some brands of laptops, especially those provided by Neuroscan, are powered by the portable power package. These computers can be purchased directly from other vendors, if desired (contact Neuroscan Technical Support for a list of these makers and models). All other configurations require the isolation transformer.

2.2 2. Connecting the Isolation Transformer

Connect the computer power supply/transformer unit to the back of the computer. Connect the other end to the isolation transformer. If you purchased the laptop computer from Neuroscan, or if you run on batteries, no isolation transformer is needed. Some additional brands of laptops may not require the transformer (contact Neuroscan for details). All other configurations require the isolation transformer.

Warning

ALL components that connect to the computer should be powered through the isolation transformer.

2.3 3. Install the SCAN Software

SCAN software is required with *NuAmps*; *NuAmps* cannot be used with other software. All files needed to run *NuAmps* are included on the SCAN CD, and are installed automatically. The details for installing the SCAN software are presented in the Installation manual. Briefly, the steps for *NuAmps* are:

1. Connect the hardware lock, or dongle, into the USB (or parallel, if older) port on the back of the computer. This is the security lock - the software will not run if this is not in place. **The dongle is essentially your license, and it is the most valuable part of the system. Guard it carefully. The replacement cost is the cost of the complete system.**

2. Start you computer. If you have Windows 2000, *you must install and run the software when logged on as the administrator*.

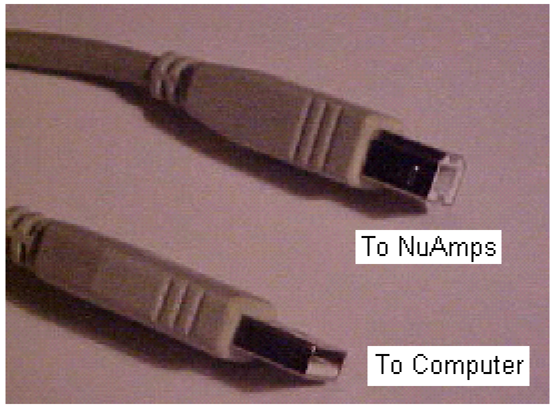
3. Install the SCAN software from the CD. The installation process should begin automatically after you place the CD in the CD drive. If it does not start automatically, run "d:\setup.exe" (or whatever your CD drive is).

4. Reboot the computer at the end of the software installation, when prompted.

2.4 4. Install the NuAmps Hardware

Locate the *NuAmps* unit, the adaptor for the STIM-to-SCAN cable (if you have STIM), the USB cable, PocketTrace and its adapter, and the amplifier stand.

1. Connect one end (the B-type connector) of the USB cable to the *NuAmps* unit, and the other end (the A-type connector) to the USB port on the host computer.



2. Connect the PocketTrace signal generator to the Cap Connector on the amplifiers, if desired. The large gray connector plugs into the cap connector, and the longer black cable plugs into the jack on the side of the PocketTrace unit (use the mini-phone jack connector that fits the cable plug). Disregard the loose touch-proof cable connectors for now. PocketTrace may be used in a variety of ways, as explained more fully in Appendix C at the end of this manual.

3. If you have a STIM system, you will have a STIM-to-SCAN cable. This sends TTL trigger pulses from STIM to SCAN. With *NuAmps*, there is a short adapter cable that connects the SCAN end of the STIM-to-SCAN cable to the serial connector (DSUB9) on the top of *NuAmps*.

⚠ Warning

Be sure to connect this cable to the trigger port on the NuAmps unit; do NOT connect the STIM-to-SCAN cable directly to the parallel port on the SCAN PC. Secure the DSUB9 connector with screws to avoid a loose connection. Do not connect any other device to the serial port except the STIM-to-SCAN cable, as other devices could damage the port.

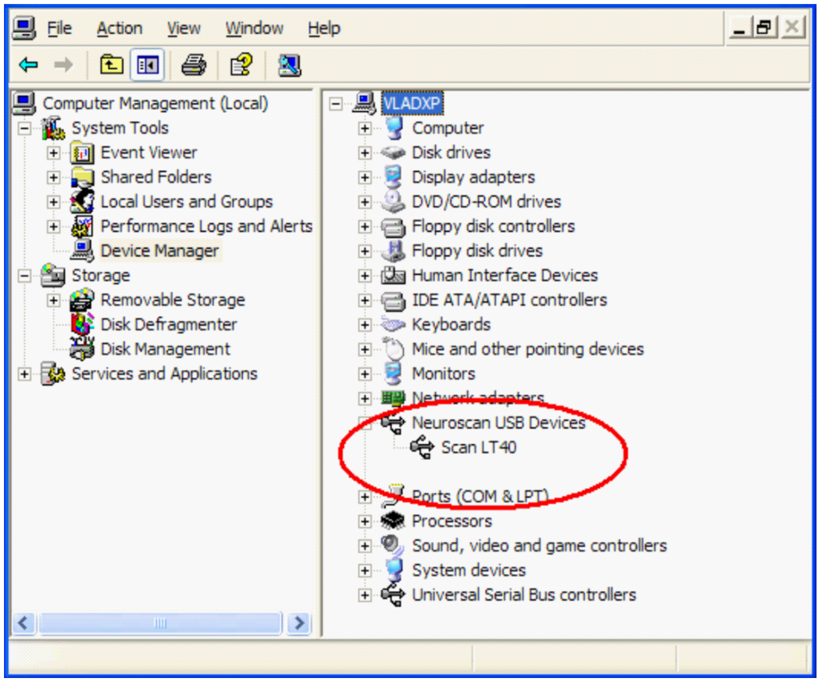
Driver verification

After installing the drivers, we highly recommend that you verify that the drivers are installed correctly as described below (the sequence is given for Windows XP/2000; other sequences can be used to accomplish the same task).

Do the following:

1. Click on “My Computer” on your desktop and select “Manage” from popup-list. The “Computer management” dialog will appear.

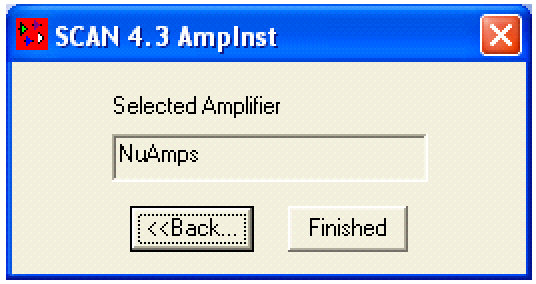
2. From the left tree view, select “Device Manager” and then expand the “Neuroscan USB Devices” branch at the right side. You should see the “Scan LT40” entry as shown below:



2.5 5. Configure SCAN for NuAmps

When the computer has booted into Windows, the next step is to install the amplifiers using the AmpInst.exe program. The program is executed by any of the conventional methods in Windows. For example, go to **Start** → **All Programs** → **Scan 4.5** and select Amplifier Install. For future convenience, you may want to create a shortcut to the program on your desktop: Amplifier Install. The Scan 4.3 AmpInst display will appear.

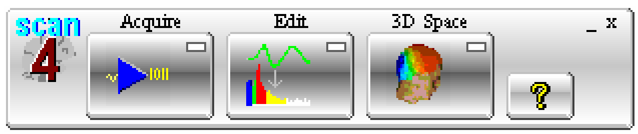
Select *NuAmps* and enable the Video Camera option if you have one installed and plan to use it with the SCAN software. Click OK. You then see a confirmation screen showing your selection. Go Back if need be, or click Finished.

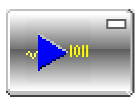


This step writes configuration information to an initialization file (you will not see anything happen).

2.6 6. Quick System Test

Click the Scan 4.5 icon on the desktop, and see the Program Launcher.

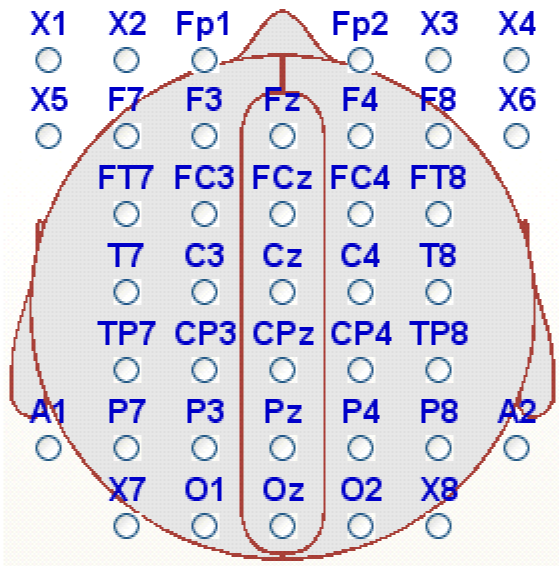


Click the ACQUIRE icon , and the main screen in ACQUIRE will appear. Click the Open File icon on the Toolbar , and select the *NuAmps40.ast* setup file (from the *C:\Documents and Settings\All users\Application Data\Neuroscan\Scan4.5\Setup Files\Nuamps* folder; in Vista, go to *C:\ProgramData\Neuroscan\Scan4.5\Setup Files\Nuamps*). Then click on the green arrow on the Toolbar  to begin acquisition. The signals from *NuAmps* will appear in ACQUIRE (flat lines are OK), and you will see "NuAmps start" on the LCD display. If the LCD does not light up, or if you get any error messages, please contact Technical Support.

3 The Amplifiers

Each *NuAmps* amplifier provides inputs for up to 40 monopolar channels, per headbox. All channels are always recorded as true monopolar channels. The active leads are referenced to the ground lead, including the reference lead(s). The reference(s) you select (from the Reference tab on the *NuAmps* Setup dialog box) is applied in the software. Bipolar channels are derived mathematically from the monopolar channels (described below).

You will see in the face of *NuAmps* the standard electrode placements, with some auxiliary ones, totaling 40 inputs.



The connector for the electrode cap is on the lower side. There are several connectors on the upper side of the unit. In addition to the USB connector, mentioned above, there are the SYNC1 and SYNC2 jacks, and a 9-pin DSUB9F connector (for use with the STIM-to-SCAN cable).

SYNC1 and SYNC2 are alternate trigger inputs for single bit TTL pulses. These are useful in configurations that include simple stimulus presentation systems other than STIM that have one or two bit outputs. A TTL pulse in SYNC1 will result in a trigger type code of 1 in the CNT file; a pulse to SYNC2 results in a 2 in the CNT file. The TTL pulses should be 5V, positive logic, with a duration of approximately 5-10ms. The jacks are 3.5mm stereo connectors with 3 contacts: 1) TTL Out, 2) TTL In, and 3) USB Ground. The TTL inputs/outputs have galvanic isolation from the patient.

Power USB Trigger port

4 Software Control of NuAmps

Data acquisition on the *NuAmps* is controlled by the host computer executing the ACQUIRE program. Acquisition, control, display and storage of data are all performed by this program. For a detailed explanation of this program, please see the Scan Tutorials and the ACQUIRE manual. The sections below describes those aspects of ACQUIRE that are specific to *NuAmps*.

NuAmps Setup Files

To record signals from *NuAmps*, you will need to use one of the supplied setup files, modify one of the supplied ones to fit your needs, or create a new setup file from scratch. Setup files contain all the system configuration information, and are stored as separate files (with an .ast extension). The following *NuAmps* setup files are installed in the *\Scan4.5\Setup Files* folder:

NuAmps 19.AST - 19 standard electrodes from 10-20 system: (Fp1,Fp2,F3,F4,C3,C4,P3,P4, O1,O2,F7,F8,T3,T4,T5,T6,Fz,Cz,Pz).
NuAmps 30.AST - 19 standard electrodes as in *NuAmps19.AST* plus 11 additional electrodes: FT7, FC3, FC4, FC4, FT8, TP7, CP3,CPz,CP4,TP8, Oz. Notice that some electrodes from the 10-20 system are labeled according to the extended 10-20 system, such as, T3->T7, T4->T8, T5->P7, T6->P8.
NuAmps 40.AST - includes all 40 electrodes found on the amplifier with labels that correspond to the amplifier overlay.

Most of the setup files have the following parameters:

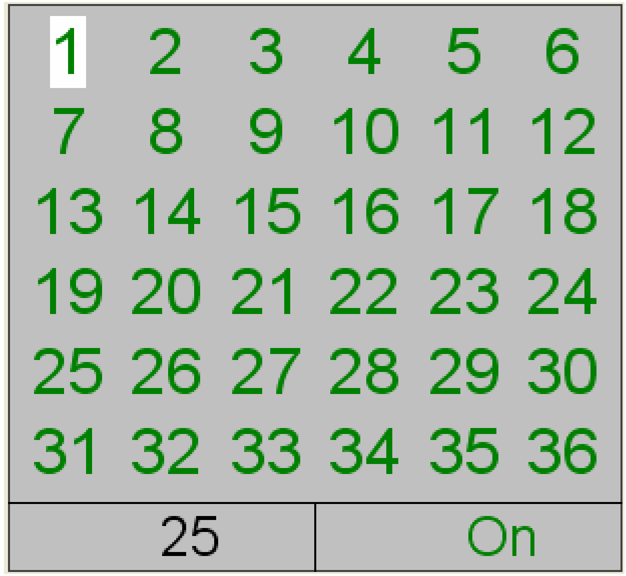
Sampling rate:	1000 Hz
Filters:	HPF 0.5Hz, LPF - 70Hz, Notch - off
Reference:	A2.

Much of the information in the ACQUIRE manual is relevant for creating setup files with *NuAmps*, and most of it will not be repeated here. The unique displays seen only for *NuAmps* are described below.

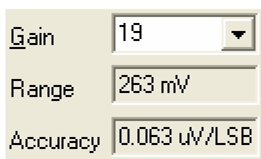
Whenever possible, you should use one of the supplied setup files; however, in some circumstances you may need to create your own. To demonstrate the process, we will create a **36** channel setup file from scratch. In ACQUIRE, select **Edit** → **Make Default Setup**, and click **OK** to the warning. This enters the default settings throughout the setup file.

Enter Number of Channels. Go to **Edit** → **Overall Parameters** and click the **Amplifiers** tab. (You may see two messages regarding high and low pass filter adjustments). Begin by entering the number of channels you wish to record, and then click the **Reset** button.

This positions the electrodes in a 6 x 6 matrix seen in the channel display.



Note that there is only one gain setting for *NuAmps* (19) which corresponds to an input range of +/-131.5mV (and 24-bits). The resolution is 131.5/(221)=0.063µV.



Range and *Accuracy* information are related to the Gain setting (there is only the one option with *NuAmps*). The Range values indicate the voltage limit (± 131.5mVs, or 263mVs, peak-to-peak) for each channel - if the incoming voltage exceeds these limits, the channel will saturate. Accuracy refers to the precision of voltage measurement along the y-axis. The value displayed indicates in microvolts the resolution ability. If the accuracy is, for example, .063µV, then the voltage resolution will be in .063µV steps. This is similar to the dwell time on the x-axis, or, in other words, the *time* difference between adjacent data points. Accuracy is the least measurable *voltage* difference between points.

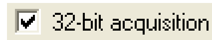
All of the other settings on the Amplifiers screen (and for the Overall Parameters settings) are as described in the ACQUIRE manual, with these exceptions.

AD Rate. There are 4 AD rates available for *NuAmps*: 125, 250, 500 and 1000Hz 

.

AC/DC. The only option for *NuAmps* is DC.

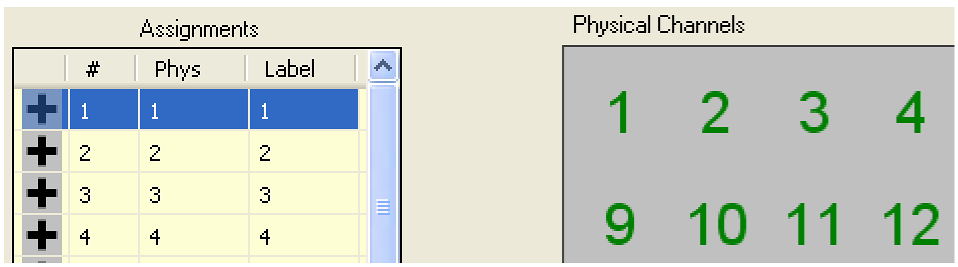
Filters. The available filter options are dependent on the sampling rate, and cannot exceed the Nyquest frequency (half of the sampling rate). As a result, if you decrease the sampling rate, the program will change the highest low pass filter that is available. Make sure this still fits your needs. High pass values vary depending on the sampling rate.

32-Bit Acquisition. The 

option lets you acquire data in either 32-bit or the original 16-bit modes. If you are recording in DC (DC high pass), you must use 32-bit acquisition because of the wider dynamic range it allows, and to record the slowest frequency activity accurately. In general, 32-bit acquisition is preferred in all cases. The one consideration is that it will essentially double the file size as compared to the 16-bit mode.

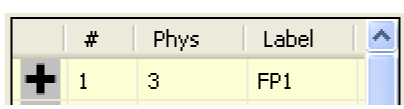
Triggers tab. With *NuAmps*, the only available triggering option on the Triggers tab is External (no Voltage triggering).

Enter Channel Labels. When you create a setup file from scratch (after selecting **Edit** → **Make default setup**), you will see numbers instead of the common channel labels. To change these, click **Edit** → **Channel Assignment Table** (shown in part).

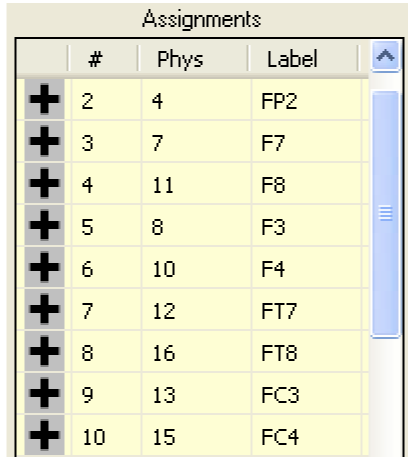


Here we need to decide the order of the channels as they will appear on the display. Let's say we want the first channel to be FP1. Note on the face of the *NuAmps* amplifiers that FP1 uses the #3 input, or third physical amplifier channel. Therefore, enter 3 in the Phys. Chan. field, and FP1 for the label.

Continue in this way to enter all of the electrodes and their respective physical channel numbers, referring to the amplifier face for the numbers. Use the electrode labels shown on the face of the amplifiers, insofar as that is convenient. You can use different labels; however, there are other sections in the program that read the labels for automatic positioning (and other operations, including mapping and source localization in SOURCE). If you use nonstandard labels, these will not be recognized.



The final Channel Assignment Table appears as follows (shown in part).



#	Phys	Label
2	4	FP2
3	7	F7
4	11	F8
5	8	F3
6	10	F4
7	12	FT7
8	16	FT8
9	13	FC3
10	15	FC4

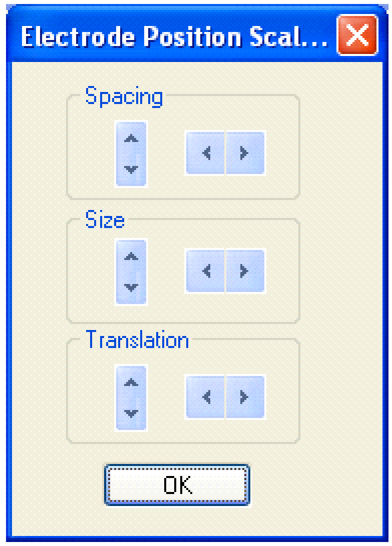
In this example, we are recording A1 and A2 as regular channels, and X1 and X2 are VEOG+ and VEOG-, respectively, and X3 and X4 are HEOGL and HEOGR, respectively (not shown above). When you are through, click OK (and save the setup file, if desired).

Channel Layout. Under Edit, select the Channel Layout option (the complete description of the Channel Layout dialog box is found in the ACQUIRE manual). Channel Layout is used to position and size the electrode displays. In this example, the positions are in a 6 x 6 matrix. You can reposition the displays manually if you want, but it is easier to do it automatically (see the ACQUIRE manual for complete details).

For now, retrieve the setup file, and go to Channel Layout. Click the 10-20 Positions button and then the Match Labels button. This recognizes the standard 10-20 system labels, and positions the electrodes accordingly. If you used different labels, will need to position those channels manually. Then click OK. The new positions will be transferred to the channel displays.

For further adjustments, click the Adjust Positions button, and see the following screen.

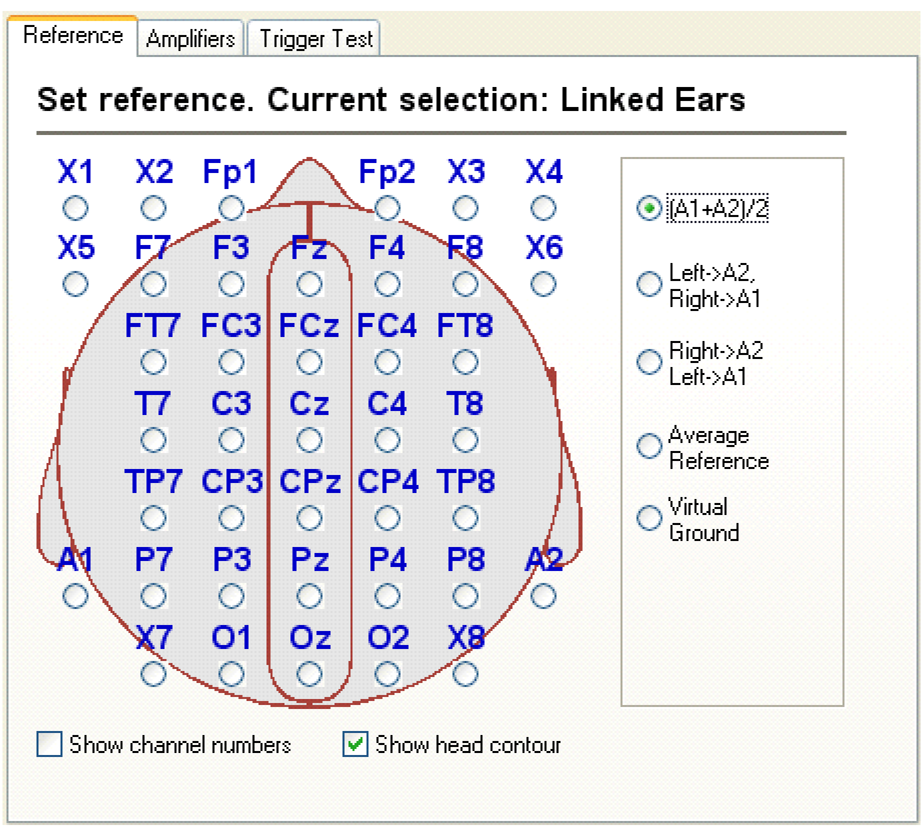
The three groups of adjustments are for Spacing, Size, and Translation. **Spacing** expands or compresses the grouping of the displays either vertically , or horizontally .



Similarly, the **Size** buttons increase or decrease the size of the electrode displays either vertically or horizontally. The **Translation** buttons will shift the entire grouping of the displays vertically or horizontally.

When you have the displays positioned and sized as desired, click OK, and then OK again. (It is a good idea to re-Save the setup file to save any changes).

NuAmps Setup Screen. Click **Edit** → **NuAmps Setup**. You will see the following display, with three tabs.



Reference. The Reference display lets you select what site(s) to use for the reference electrode. The *NuAmps* amplifiers are different from most other amplifiers. The main point to understand is that the reference is computed in the software. That means there are few limits on what can be used for the reference. You can select a single electrode, used linked or single ears, and so forth. Let's say you want a linked ears reference. That is the first option (A1+A2)/2. Click that button, and you will see the current selection written at the top of the display.

Set reference. Current selection: Linked Ears

As mentioned, you have a great deal of flexibility in the selection of the site(s) for use as the reference. To select a single channel, such as Cz, just click the Cz field. You will see the choice indicated in the top line of the display.

Set reference. Current selection: Cz

The complete list of reference options are:

(A1+A2)/2: This is the linked ears option.

Left=>A2, Right=>A1: This option uses the contralateral ear/mastoid as the reference.

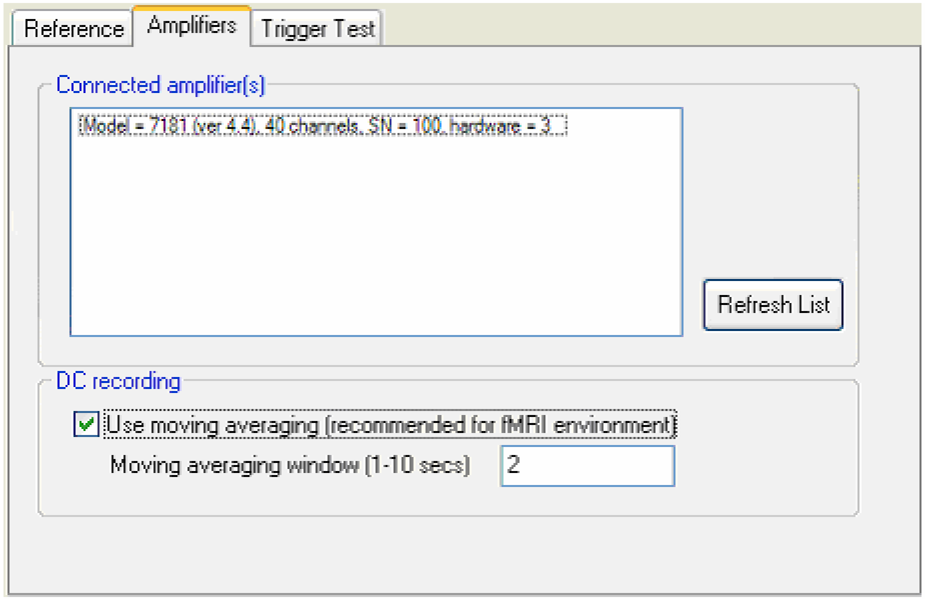
Right=>A2, Left=>A1: This option uses the ipsilateral ear/mastoid as the reference.

Average Reference: In this case, all specified electrodes are recorded and the averaged potential is calculated and subtracted from original signals. Only actually placed electrodes are used. For example, if you specify 10 electrodes to be recorded, but only place 8 of them, then only this group of 8 electrodes will be used.

Virtual Ground: This option should be used only for demonstration purposes while recording signals from the PocketTrace signal generator. In that case, the program displays pure potentials under active electrodes relative to ground. Such traces, however, may have 50/60Hz noise, DC drift, etc. The Virtual Ground can be used only for high amplitude signals such as ECG. For low amplitude signals, like EEG, differential montages are used, and the reference potentials (for example, the earlobe) are subtracted from the active potentials.

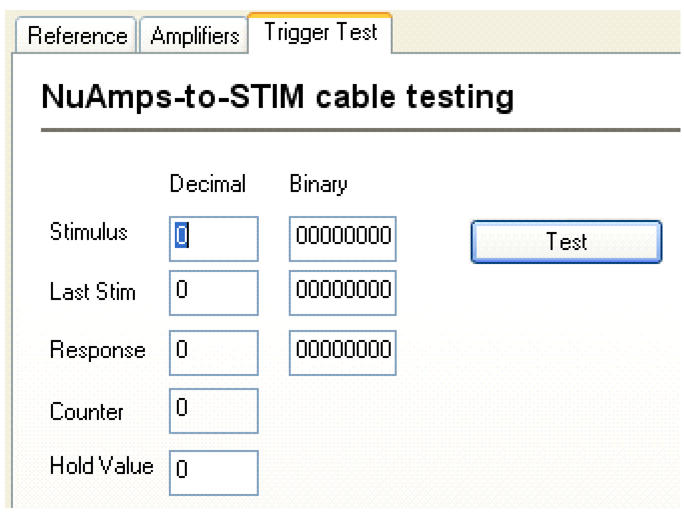
Note that you have the options to display the head contour and the channel numbers at the bottom of the display.

Amplifiers. Click this tab to query the *NuAmps* headboxes you have attached.



If you are recording in the 16-bit acquisition mode in an fMRI environment, it is recommended that you enable the "Use moving average" option, and then select a window from 1-10 seconds. The option is not needed with 32-bit acquisition. (*NuAmps* are not recommended for use in the MR because the sampling rate is too slow to capture the trigger precisely enough to permit artifact removal).

Trigger Test. The Trigger Test option is used for diagnostic purposes if you are having triggering problems. It reads the status of the serial port on the *NuAmps* trigger input. Its operation is described in Appendix A at the end of this manual.



This completes the basic steps for creating a setup file for *NuAmps* (save the setup file). You might also want to create bipolar and other re-montaging files. This process is described next. If you purchased a photic stimulator, you will also need to set up the recording sequence. This is described in the Photic Stimulator manual.

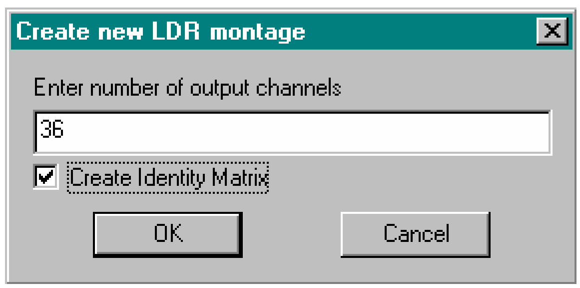
Creating a Bipolar Montage. *NuAmps* records all channels as monopolar channels, referenced to ground. The Reference you select is applied in the software. Bipolar montages are computed from the referenced EEG signals by simple subtraction. The Montage Editor is used to create an LDR file (linear derivation file) that performs the subtraction. The complete operation of the Montage Editor is explained in an appendix to the EDIT manual. We will demonstrate here how to create a simple LDR file that can be used to compute selected bipolar channels. (You can create, modify, or apply the LDR file online in ACQUIRE or offline in EDIT. We will demonstrate the online option here).

In this example, we have a VEOG+ electrode (above the eye) and a VEOG- electrode (below the eye), and we want to create a bipolar channel: VEOG+ minus VEOG-.

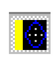
1. In ACQUIRE, retrieve the setup file you will be using.

2. Click the Montage Editor icon from the Toolbar .

3. In the Montage Editor, click File, then Create New Montage.



Use the same number of channels, but make sure you click the Create Identity Matrix field. This creates an output LDR file that is identical to the original one. The matrix will show a 1 in each cell as you look down the diagonal from upper left to lower right cells. Click OK.

4. Unclick the Show Head Contour icon . This lets you see more of the matrix.

5. Right click on the VEOG+ label in the column on the left, and select Rename channel. Enter BipVEOG (for bipolar VEOG). *Do NOT use spaces in the new label names.*

6. Right click on the VEOG- label, select Delete channel, and delete the VEOG- channel (ignore the warning message). This is not mandatory. We are setting up the LDR file to show the single bipolar artifact channel. We could also keep the existing VEOG channels and create an additional bipolar one.

7. Now, look on the row corresponding to the BipVEOG channel we are creating. Look at the intersection of the BipVEOG row, and the VEOG+ column. There should be a 1 in that cell already (created when we selected the identity matrix option). Now find the intersecting cell for the BipVEOG row and the VEOG- column. *Add a -1*

in the cell in the VEOG- column.

(0:0)	F7	FP1	VEOG+	VEOG-
F3	0	0	0	0
FP2	0	0	0	0
F7	1	0	0	0
FP1	0	1	0	0
BipVEOG	0	0	1	-1

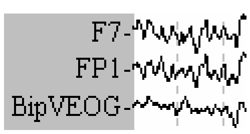
This says to take each original data point from the VEOG+ column and multiply it by 1 (no change), and to take each data point in the VEOG- column and multiply it by -1. The new channel, BipVEOG, will be the linear sum of the data points for all channels in the row. Each new data point will be VEOG+ minus VEOG-, or the derived bipolar channel. (The other channels are all zeroes, and do not contribute).

8. Click File, then Save Montage File. Enter a file name, and *be sure the "Save as type:" field is set for Linear Derivation Files*.

The LDR file that is created can be applied anytime you use the same setup file, or with any data file recorded with that setup file. Once the LDR is created and saved, you do not have to create it again. Close the Montage Editor.

9. In ACQUIRE, when you are acquiring data (Single Window Display only), and wish to see the derived bipolar channel, all you need to do is right click in the data display and select Add Derivation.

Select the LDR file you just created, and you will see that data displayed with the new channel.



Click Remove Derivation (right click menu) to restore the data to its original form. In the offline EDIT program, you can apply the LDR file in the same way, or you can apply it with the Linear Derivation transform (to save the new file).

5 DC Electrode Considerations

The DC capability of the *NuAmps* amplifier presents special requirements that most electrophysiologists more familiar with AC coupled systems may not have encountered. With DC amplifiers, battery potentials generated from electrodes are not dissipated by the decoupling capacitors found in AC only systems. *NuAmps* cannot correct offset voltages greater than plus or minus 130mVs. Electrode combinations generating battery potentials greater than 130mV will saturate the amplifier. Saturation will become evident when the amplifier displays a flat line with no apparent activity and a saturation value greater than 100% is displayed. Under normal operating conditions you should not experience saturation values greater than about 30%. **If your electrodes show a consistent DC shift that climbs quickly to saturation, then your electrodes are not suitable for DC recordings.** There are several rules to follow when selecting electrodes to avoid these problems:

1. **Never use different combinations of paste/gel and or electrodes.** For example, a common error is to use one type of electrode and paste in a monopolar derivation (i.e., electrode cap and gel) and a different electrode and or paste on the reference lead. By using different metals and electrolytes a battery potential has been created and the electrodes will drift. If you have the same electrode materials and gel and you are still experiencing saturation, then double check your electrodes. They may not be made out of identical material. Measure the DC voltages across these leads and you will possibly find a large offset potential.

2. **Keep the interface between the skin and electrode consistent**. For example, with an electrode cap the interface with the skin is a nonconductive rubber and the conductive gel. The gel makes contact with the electrode. If you place a reference electrode directly on the subject's skin for a reference, you have created a different interface. You now have a gel plus metal to skin interface. The best way to avoid this problem is to obtain a separate but identical electrode to employ as a reference. Another technique is to separate the metal from the skin with an adhesive electrode collar. *Note - drift problems with the reference electrodes in multichannel recordings are usually observed across all monopolar derived electrodes.*

3. **Select metals that are known to produce the smallest battery potentials.** Sintered Ag/AgCl electrodes are probably the best and easiest to obtain. If you use these electrodes, remember to take care not to scratch the surface.

4. **The DC level is relatively independent of the electrode impedance.** If you have set your electrode impedances to the standard 5kOhms or less and your electrode is still drifting, additional work on the impedance will usually have no effect (except on the subject). Since the primary source of battery potentials is the interface between the gel and electrode and not the skin, further work on the gel to skin interface will probably not help. This is a good time to replace the electrode or examine the metal to wire solder joint (another potentially large source of battery potentials).

5. **Record in a comfortable and cool environment**. Sweat potentials can be a major problem for DC recordings. They produce transient and unpredictable results.

On some AC coupled systems, high-pass values below .1Hz are often available as an approximation to DC. If you are interested in slow potentials, there is no need for these values since the *NuAmps* is a DC coupled system. The advantages to recording slow potentials with a DC high-pass are two fold.

First, **DC amplifiers are less prone to impulse artifact**. The recovery time of an AC coupled system (actual or simulated as is the case on the *NuAmps*) can be described by the time constant of the system. The time constant is the time needed by an amplifier to decay to 37% of the peak response to a sudden impulse. To calculate the time constant of a simple filter use the following formula where T is the time constant and f is the cutoff frequency:

$$T = \frac{1}{2 \cdot \pi \cdot f}$$

This formula can be used to determine the effects of high-pass filter values you may have on your recordings. For example, if the amplifier encounters an impulse artifact with a 0.01Hz high-pass filter, it will require 16 seconds before the system returns to 37% of the original amplitude! If you are using such a filter setting so as to approximate DC, we strongly recommend that a DC value be employed. The DC setting is insensitive to impulse artifact. The *NuAmps* is not affected by even the most substantial of artifacts such as those generated by somatosensory and magnetic stimulators when recording in the DC mode.

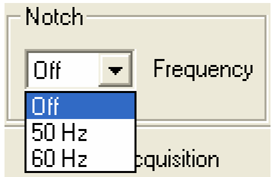
AC coupled systems that employ long time constants such as .01Hz can be very unstable and are highly susceptible to sudden impulses (movement artifact) causing the subsequent smoothing of the impulse, consequently, these amplifiers saturate and need an external reset circuit to restore the system.

Second, a **DC recording can always be refiltered with different high-pass values**. Digital filtering can be applied to the data to examine the effects of different high-pass values. This is not true, however, if the data have been acquired with an AC coupled system. You will have to accept whatever high-pass values were originally used to sample the data. In addition, digital filtering (in both EDIT and ACQUIRE) can offer sharper frequency cutoffs without the phase shift of an analog filter.

6 Notch Filters and Noise

Narrow band notch filters centered at 50 and 60Hz are available to reduce main power frequency interference. Although these filters have a $\pm$1Hz window, and affect a narrow range of the EEG spectrum, caution should be exercised in their use. Many evoked potentials have energy in the 50-60Hz band and data may be significantly distorted. Notch filters should not be used routinely. Rather, attempts to reduce noise in the recording environment should be made first before adding a notch filter.

The option for the filter is found in the **Amplifiers** section under **Overall Parameters** .



60Hz (50Hz) Interference - Here are a few quick things to check if you have significant interference in your data:

Impedance of leads - Impedances of all leads should be below 5kOhms.

Impedance of ground lead - It is important that a solid ground lead be placed on the subject. The ground lead is used by the amplifiers to reject common-mode interference such as 50 and 60Hz main frequencies. Double check this lead to be sure it also is under 5kOhms.

Warning

If all of the channels show high impedance values, this is an indication that the Ground or Reference electrodes have high impedances themselves.

Power cables - Make sure that there are no power or video cables near the electrode leads, the subject, or the amplifiers. Position the USB cable so that it does not cross the electrode leads. Although signals coming from the amplifiers are amplified, draping a power cable over the amplifiers or amplifiers cable will produce interference.

Power supply - The power supply for your laptop computer can introduce line noise. If you encounter excessive noise in the recordings, try running on battery alone. If that resolves the problem, it may be that the power supply is just noisy, or, there is not a true earth ground.
Monitors - Video monitors are now a common device in the neurophysiological laboratory. Unfortunately, they can also be a serious source of interference, especially the older ones. Most monitors radiate more from the sides than the front. If you suspect interference from your monitor, try moving the orientation of the screen. It should vary with orientation. Another clue that a monitor is emitting noise is a clear pulse with an interval corresponding to the refresh rate of the screen (i.e., 16.667 ms for a 60Hz refresh rate). It should be noted that the newer low radiation monitors have significantly reduced noise radiation.

Other noise sources - Watch out for anything in the surrounding area of your laboratory that can generate an electromagnetic field. Any device with a large electric motor (centrifuges, freezers, elevators, large fans) or transformers (X-ray machines) is a potential problem. Also, check to make sure that you have a good and 'quiet' ground connection within your building. A high quality milligauss meter can be used to measure these fields.

7 Calibration

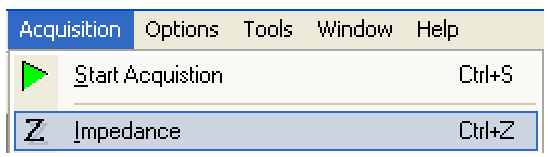
Calibration of *NuAmps* is performed only in the factory, and no amplifier adjustments are possible on site. Inter-channel variations of ±1% are expected, even with high precision elements.

It is possible to measure the variation across amplifiers using an external signal from, for example, PocketTrace. Set it to produce a sine wave at, say 10Hz (see the PocketTrace Appendix for details). PocketTrace will deliver the signal to all channels. Measure the peaks in ACQUIRE, or, save the file, perform an FFT, and compare the peaks at the frequency you selected.

8 Impedance

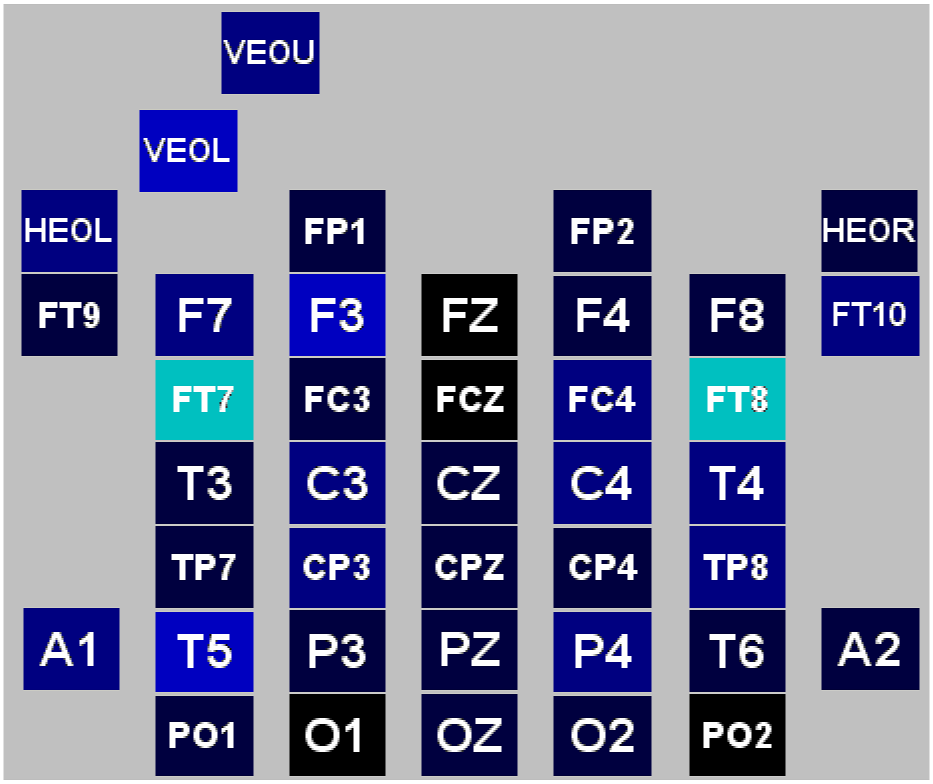
Electrode impedances can be checked at any time while the subject is connected to the amplifiers. The leads are measured against the reference; the GND lead is used for recording signals. Therefore, all measurements for these leads will be affected by impedance of the reference and GND. (See Appendix E for more details). Follow these steps to check electrode impedance:

Step 1 - Place leads on the subject with standard electrode application techniques. If you want to see the impedances as you place the electrodes, be sure to place the ground and reference ones first.

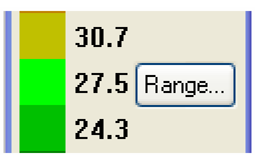
Step 2 - Click on the 

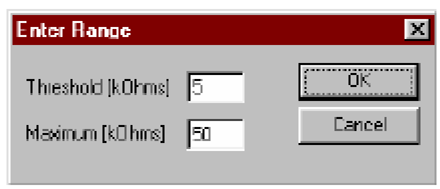
option under Acquisition from the Acquire Main Menu bar, or by clicking the Impedance icon  from the Toolbar. The 'Impedance' display screen will appear.

The impedance of an electrode, or the opposition of AC current flow, is the result of the complex interaction between skin, electrolyte and electrode. Measured impedance will vary according to the transfer function of this junction.



Step 3 - Enter the threshold and maximum displayed impedance value. The default threshold value is 5kOhms, and the maximum value is set to 50kOhms. To change these, click on the **Range...** button and enter the desired values. Then click OK.





Step 4 - Impedance testing will begin when the Impedance screen is displayed. The impedance operation uses a 30Hz sine wave. The color-coded impedances will be displayed for each electrode according to the color of the display.

NOTE: The impedance of the Reference electrode cannot be measured by NuAmps, and it will always show pink in the impedance display, indicating maximum impedance.

9 Subject Ground

The subject ground should be placed as close as possible to the recording electrodes. Under most circumstances this location is somewhere on the head. The subject ground is used to reject common mode noise. Therefore, by placing the ground near the recording electrodes the common mode rejection ability of the amplifier is optimized. Avoid placing the ground at distal sites (arms and legs). An older technique often used to reduce stimulus artifact was to place the ground near the stimulating site. However, this procedure should not be used on *NuAmps* and will degrade system performance. Do NOT add a second subject ground. A ground loop could result, thus introducing 50 or 60Hz noise in the recordings.

10 Electrode Safety

The *NuAmps* amplifier inputs and attached electrodes are Type BF, which means in part that they are not connected to Earth Ground or Chassis Ground. Maintain this separation from Earth Ground by ensuring that the electrodes and any conductive parts of their connectors do not touch conductive parts, including the system enclosure or other grounded devices.

11 Troubleshooting

The most common problems while recording *NuAmps* are described below. If your problem is covered in this section, follow the instructions and try to resolve the problem by yourself before calling tech support.

1. **NuAmps amplifier is not detected or is not sending signals.**
   The amplifier may not be detected, or may appear to not be functioning, for several reasons. The amplifier may not be connected to your computer by the USB-cable. The USB-cable may be broken. The Driver may not be installed properly - that can happen if you attached the *NuAmps* amplifier to your computer before you installed SCAN software. As a result, Windows failed to find the correct driver. Least likely is that there is a hardware failure in the amplifier.

   Make sure the amplifier is connected to the computer by the USB-cable. Check the power LED on the amplifier. If the LED is on, proceed to the next step. Otherwise reconnect the USB-cable and check the LED again. If the LED is still off, replace the USB-cable, and try again. If the LED is still off, the amplifier is possibly broken and you need to contact tech support.

   If the power LED is on, open the "Device Manager" and verify that you can see the "SCAN LT40" device listed under "Neuroscan USB devices". If the device was recognized, proceed to the next step. If it is not, reconnect the *NuAmps* to another USB-port on your computer. If your system does not react to the *NuAmps* connection, either the *NuAmps* or the USB-port on your computer is broken. Connect the *NuAmps* to another PC; if another PC reacts on that connection, then the USB-port on your computer is broken. Otherwise, it is a *NuAmps* failure and you need to contact tech support.

   If a question mark is shown next to the *NuAmps* icon, or if the *NuAmps* appears in the "Other devices" section, you need to re-install the driver. Right click on the icon, select "Update driver", and follow the instructions from the "Installing NuAmps" section above (4. Install the *NuAmps* Hardware).

2. **Acquisition starts but all signals are flat.**
   There are several possible reasons for flat line signals. The wrong vertical scale may have been selected. Make sure that the vertical scale is selected around 100-200μV, otherwise you will not see a signal. It is possible that the Reference or Ground electrode has not been applied. Make sure you prepare the skin for the Reference and

Ground electrodes with maximum care to reduce compound impedance. Verify the physical connection of the Reference and Ground electrodes between the subject's head and amplifier. Use a multi-meter to check the continuity of the electrode wires. Also make sure that you are using the same Reference that is specified in the software.

The wrong type of electrodes can result in signals that are saturated beyond the range of the amplifiers. If a high pass filter is applied to a saturated signal, the signal will appear as a flat line. Check the saturation level at the left side of ACQUIRE screen. If the signal is saturated, consider switching to Ag/AgCl electrodes which normally show DC shifts below 10%.

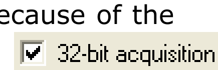
Verify that you have connected the QuikCap to the amplifier.

3. **No triggers are detected.**
There are several ways in which triggers can be lost. Generally these are easy to resolve, once you determine what the cause is. The simpler causes are with the connections. Make sure the *NuAmps*-to-STIM cable and stimulation cable are attached appropriately. Verify that all cables are connected tightly and try again. If no triggers are seen, proceed to the next step.

Verify that the stimulation system is powered from the same wall outlet as the SCAN system. Usually this is not a problem, but in some facilities there can be differences in voltages. As a result, the TTL logic is not defined between the two systems, and the triggers are not detected.

If that does not solve the problem, there could be a defective cable (shorted or broken wires). Disconnect the STIM system from the *NuAmps*-to-STIM cable and test if triggers are working by “NuAmps Setup” dialog, using the “Triggers” page (see Appendix A for more details). Press the “Test” button and short pin 25 (GND) to pins 1-8 and 21-24. As you short the pins, the state should change. If not, then the *NuAmps*-to-STIM cable is broken, and you need to contact tech support. If the bits themselves are functioning, there may be a problem with the stimulus presentation system (such as a "stuck bit"). Refer to Appendix A for testing directions. It is likely, however, that if the problem is not cable related, there is a hardware failure, which may necessitate the return of some components.

4. **The amplifier is not responding.**
In most cases, this indicates that the correct driver is not installed. See the Driver Verification section above for more details. If that looks correct, contact techsup@neuroscan.com for assistance. There are no accessible parts in the *NuAmps* that can be repaired on-site. A genuine hardware failure will require a return for repair, as will Firmware updates in many cases.

5. **Saturation of signals.**
Saturation and clipping of signals should be a very rare occurrence because of the broad dynamic input range of the *NuAmps* amplifiers. Try enabling the 

option (**Overall Parameters** → **Amplifiers**). This will give the broadest dynamic range. It is better, however, to remove the cause of the drifting. When saturation occurs, it is usually because you are mixing metals among electrodes, especially for the ground and/or reference electrodes (if all channels are affected). It can also occur if the ground/reference electrodes are not well applied (high impedance). See the "DC

Electrodes Considerations" section above for more information. It can also occur if the ground/reference electrodes are in need of cleaning or replacement.

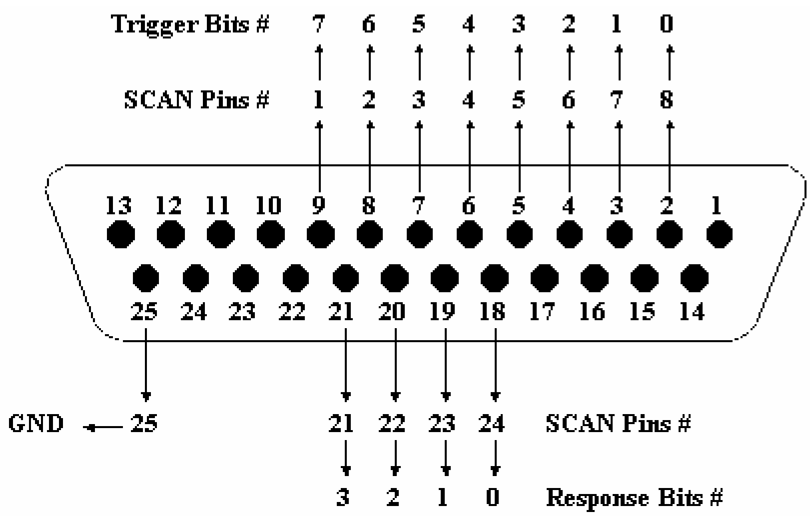
7. **Missing triggers.**
   You are seeing some or most of the triggers, but occasionally some are missed. If you are using a stimulus presentation other than STIM, be sure that the duration of the TTL pulses is at least 100 microseconds. Anything shorter than that may be discarded as noise. The optimal TTL pulse width for *NuAmps* is 500 microseconds. Assuming the trigger pulses are being sent reliably from your stimulus presentation system, missing triggers can occur if the SCAN and STIM systems are plugged into different power outlets, in which case the TTL logic between systems may be undefined. (In an earlier version of the software, there was a problem in the DLL file that could result in missing triggers; please contact techsup@neuroscan.com if other potential causes have been eliminated).

8. **Increased line noise on some or all channels.**
   If you see increased 50Hz or 60Hz line noise on all channels, the most likely causes are high impedance (poor application) at the ground or reference electrodes, poor earth ground in the building, or the presence of emanated noise from some nearby equipment (see also the "Notch Filters and Noise" section above). The most likely cause of increased noise on a few channels is high impedance for those channels. If the affected channels are all from the same area (such as the front of the head, decreasing posteriorly), look for a radiating source from some other device in front of the subject (such as an older PC monitor).

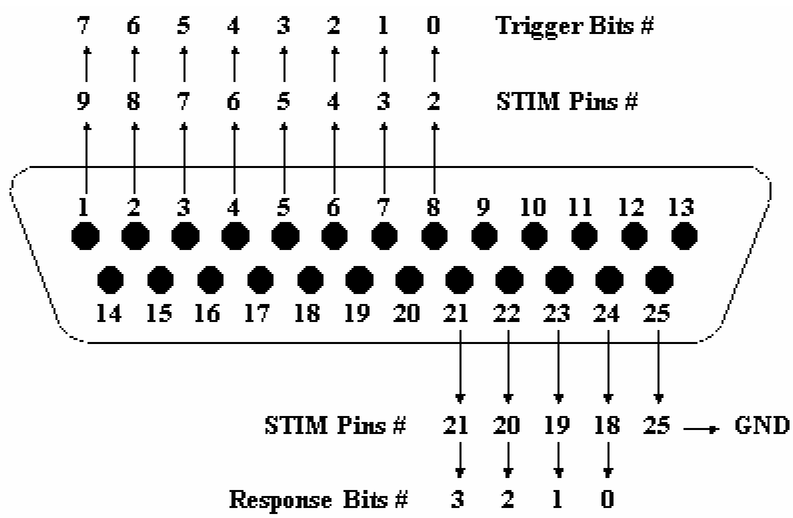
   The quality of any electrode is related to 1) how the skin was prepared by technician; 2) surface of electrode (Ag/AgCl electrode surface can be damaged); 3) how electro-conductive paste or gel was applied, or if gels with differing conductive properties were mixed. The most common problem is the first one, which is directly related to technician experience. Environmental noise can arise from: 1) proximity of power lines and impulse generating equipment; 2) quality of ground line; 3) crossing of electrode leads by a power line; 4) proximity of the subject's head to noise emitting equipment, e.g., computer screen. In addition, if you place an electrode with high impedance (> 15kOhm), *NuAmps* will still record EEG because of its high input resistors (=100MOhm), but then any patient movement or movement around him will generate an "antenna" effect.

12 Appendix A: Trigger Port Interface

The method of triggering between the SCAN and STIM systems is to connect the Parallel I/O ports on the back of the *NuAmps* and STIM interfaces by means of a STIM-to-SCAN cable. This cable is provided to customers who purchase STIM systems. A STIM-to-SCAN cable is a grey, 25-line cable with a female connector at the end marked SCAN and a male connector at the end marked STIM. A parallel-to-serial cable is provided with *NuAmps* to allow input into the *NuAmps* unit. Below are diagrams of the STIM-to-SCAN cable connections.



Back of STIM Connector



Back of SCAN Connector

Response pad pins

On the back of the STIM connector the response pad lines are 21, 20, 19, 18, carrying response bits 3, 2, 1 and 0. On the back of the SCAN connector the response pad lines are 21, 22, 23, and 24, carrying response bits 3, 2, 1 and 0.

Matching Port Logic

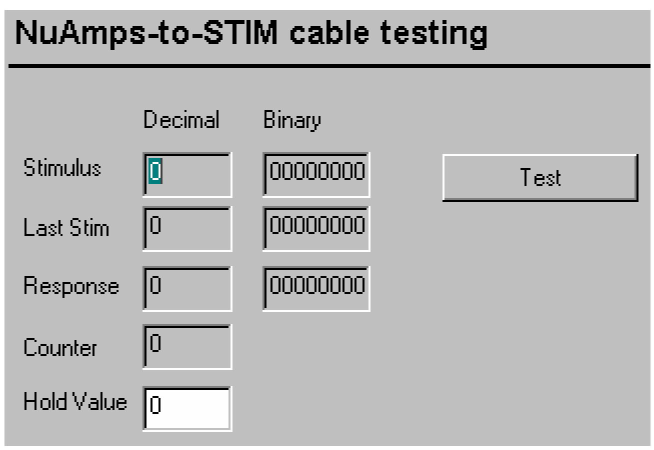
The logic used to trigger your system can be either positive or negative. Positive logic is defined as a transition from the zero state (ground) to a one state (5V TTL). Negative logic is defined as a transition from the one state to the zero state. The *NuAmps* employs positive logic on the stimulus port and negative logic on the stimpad (response port). *Note - the stimpad lines must be held to positive levels during the resting state or the device will not respond. If not connected these lines are 'pulled-up' to high levels.*

Because *NuAmps* uses positive logic on the stimulus port the numbers received by the trigger port from older 100kHz based STIM systems (identified by the two large ribbon cables exiting the back of the computer labeled J6 and J11) need to be inverted back into positive logic to match the *NuAmps*. This is accomplished by the **Use inverted values** option in Acquire, under **Edit** → **Overall Parameters** → **Triggers** (see Acquire manual). In general, if trigger codes do not match (i.e., a 1 generates a 254) then the **Use inverted values** option should be used.

Troubleshooting

If you encounter problems with triggering, there are a number of procedures that you can follow to determine the cause of the problem. Most triggering problems are simple to correct. These are described completely in an Appendix at the end of the Installation/Orientation manual. The sources of the problem can be on the STIM side, the *NuAmps* side, or the connecting STIM-to-SCAN cable. Only those problems relevant to the SCAN side with *NuAmps* will be discussed here (refer to Appendix mentioned above for other potential causes).

The *NuAmps* Setup option, under Edit, has the Trigger Test tab. This reads the status of the bits at the trigger port on the *NuAmps*. It provides a quick means to see what the problem is and where the source is.



The Decimal column will show the type code numbers that are sent from STIM. The Binary column will show the bits as they change. Bit 0 is on the far right side of the display, and bit 7 is on the far left side.

Stimulus. The Stimulus fields display the stimulus trigger type codes received. With STIM running, you will see brief flashes in the Stimulus decimal and binary fields with each trigger received. If you increase the pulse duration in the STIM software to, for example, .1s, you will see the triggers somewhat more clearly. The type code number will flash on the decimal field, and the activated bits will flash on the binary field.

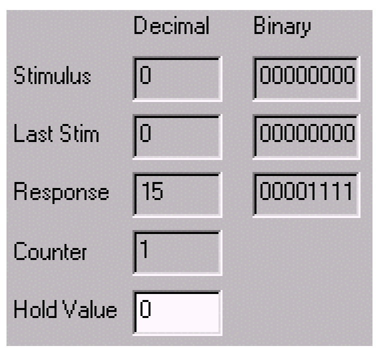
Last Stim. The Last Stim fields will show the type code in decimal and binary of the most recent trigger.

Response. The Response decimal field will show the inverted value of the response pad triggers (i.e., 255). Pressing the response pad buttons should show decimal values of 254, 253, 251, and 247, corresponding to buttons 1-4, and type codes of 1, 2, 4 and 8, respectively. The binary field will be all 1's until a button is pressed, then the corresponding 1 will become a 0 (uses the 4 columns on the right side of the display).

Counter. The Counter will show the accumulated number of stimulus and response triggers received.

Hold Value. The Hold (bit pattern) value determines what value of the signal at the trigger port will initiate a sweep; a value other than the Hold value will trigger acquisition. With new STIM systems, the Hold value should be zero. If you see a different value, please contact Technical Support. If you have an older LabMaster STIM system, and do not see any triggers with a Hold value of zero, you need to invert the trigger codes. Do this by entering 255 for the Hold value from the keyboard (you will need to click the *Use inverted values* field under Edit/Overall Parameters/Triggers). If you still do not see triggers, contact Technical Support.

With the STIM system turned on (but not sending triggers) and the stim-to-scan cable connected, go to Trigger Test, and click its Test button. If everything is functioning normally, you should see:



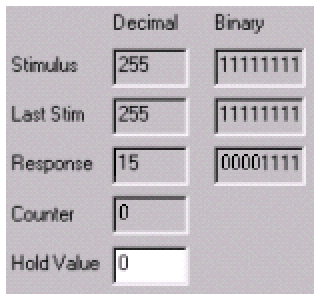
In its "resting" state, note that the Stimulus bits are at zero, and the four Response bits are held high (all 1's). Summing the 4 response bits gives the 15 Decimal value. The Hold Value should be 0.

If you see, for example, one (or more) of the stimulus bits held high (1), that will cause all other incoming triggers to be ignored (no triggers). A workaround is to take whatever number it shows in the Stimulus field, and enter that as the Hold value. For example, if the 4th bit is stuck (8), enter 8 as the Hold value. (The events seen in ACQUIRE will be altered accordingly - this is a temporary workaround until the real problem is repaired). The cause could be a problem in the STIM box, the stim-to-scan cable, or the trigger input circuitry in the *NuAmps*.

With other stimulus systems connected, you might see all response bits at 0. They all need to be high in the resting state. Then it is a question of whether you want to record responses or not. If you do not want responses, then you should not plug anything into those pins on the SCAN side of the trigger connector (pins 17-24). The natural resting state of the *NuAmps* is high, so they will be OK. If you do want responses, they must use inverted logic, where the resting state is high, and the trigger pulse goes to zero.

Now start a program in STIM that sends stimulus triggers, and/or press the buttons on the response pad. You should see the corresponding bits (the 1's and 0's), toggle on and off. These will be very brief - increase the duration of the trigger pulse in STIM to make the toggling easier to see.

To help isolate the cause of abnormal bits, disconnect the STIM-to-SCAN cable from the back of *NuAmps* (and Start Test trigger port). You should see:



All of the bits should be high, except for the 4 response bits. If any others are at zero, that points to a problem in the *NuAmps* (and a probable return to Neuroscan). If this looks normal, connect the STIM-to-SCAN cable to the *NuAmps*, and disconnect it from the stim box. It should still look like the picture to the left (the Counter might increment). If the readings change, there is a problem in the cable. If it still looks normal, then the problem is likely on the STIM side.

When you are testing for triggers in ACQUIRE, using the Single Window display to see the triggers in a continuous file, be sure you have NOT enabled the “Use inverted values” field in the setup file (look under Edit, Overall Parameters, Triggers).

13 Appendix B: NuAmps Electrode Starter Kit

Your system will arrive with an Electrode Starter kit, and/or a *NuAmps* Quik-Cap(s)TM, if you purchased them. Application of the electrodes will vary depending on which you have.

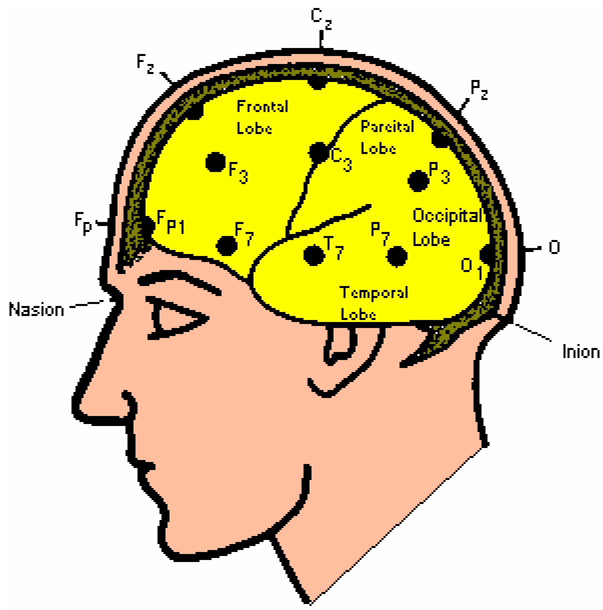
The *NuAmps* Starter Electrode Kit contains 40 electrodes and a container of Ten20 paste, with some additional accessories. These *NuAmps* electrodes feature:

- Silver / silver chloride electrodes are standard, but, by special order, you may have received sintered silver or gold electrodes.
- All discs are 10mm (0.4in) in diameter and come with 1.5m color-coded wires. That length ensures a comfortable recording environment.
- The electrodes have touch proof protectors, which prevent the wire from breaking down while bending in any direction. This dramatically extends the life of the electrodes.
- EEG wires are coated with Teflon to resist tangling. Electrodes that are jumbled together easily pull free.
- Electrodes are cupped, with the hole at the peak, to facilitate better contact with electrode paste. The hole is used to refill conductant during prolonged recordings.

Ear clip electrodes are not necessary, and any electrode can be placed at the reference point.

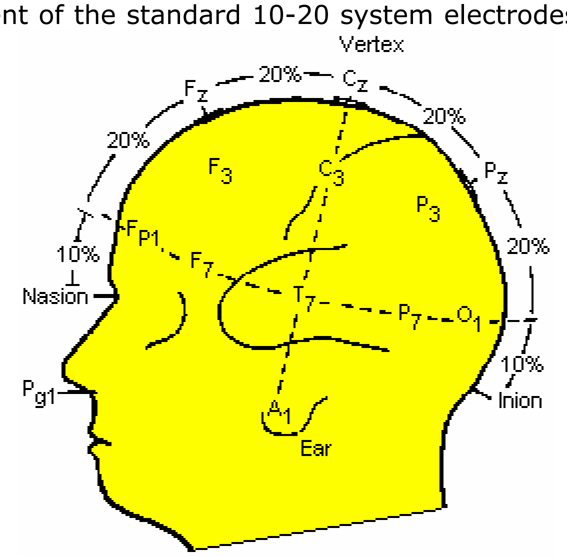
We are assuming that registered EEG technicians will be recording the EEGs, and the information below should augment your existing knowledge.

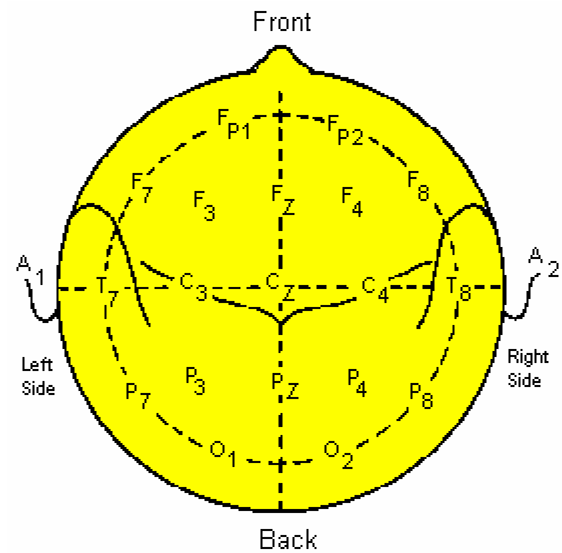
With individual electrodes, you can place them anywhere, although the International "10-20" system is used for labeling in *NuAmps*. We recommend you adhere to the 10-20 (or modified) system to avoid confusion. The caps follow the modified 10-20 system, with its additional electrodes.



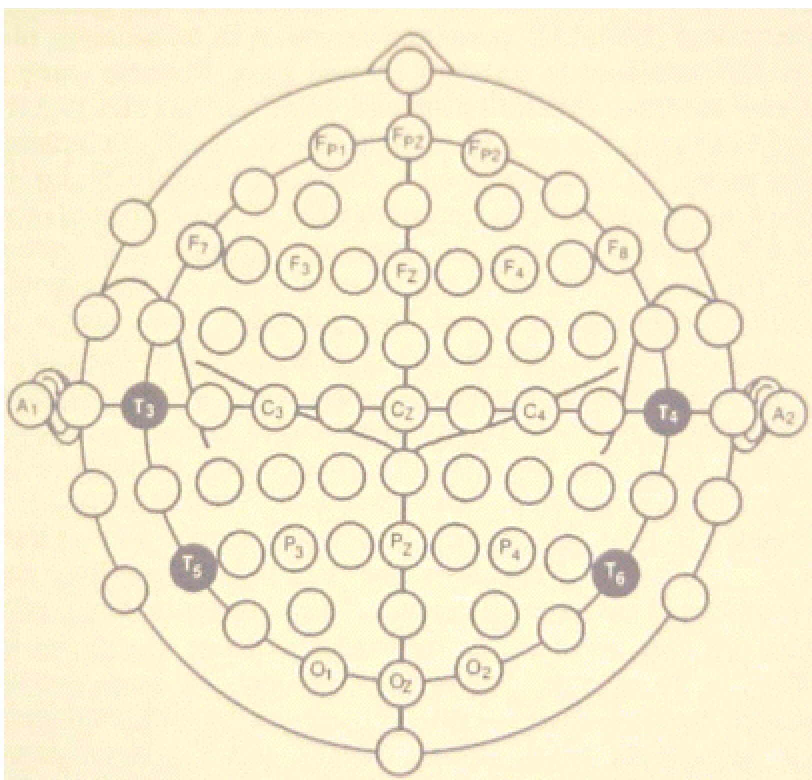
The basic 10-20 system is as follows. Electrodes are placed over the various lobes of the brain, and the electrode labels identify the lobes over which they are positioned. Odd numbers are from the left side of the head, even numbers are from the right side, and electrodes down the middle have a "z". (While there is no central lobe, the label C is used for convenience). For example, the F3 electrode is from the frontal lobe on the left side. Cz, or Czed, is placed at the vertex at the top of the head. Precise placements use percentages of distances measured from landmarks on the head - the nasion (the dented junction of the nose and the forehead), and the inion (the bony protuberance at the back of the head.

Diagrammatic placement of the standard 10-20 system electrodes is as follows.





The modified 10-20 system uses these same electrode positions, as well as additional ones that fall in between these positions. For example, FC3 lies halfway between F3 and C3. An approximation of the modified system is below.



Appropriate spatial sampling of potential fields requires regular placement of electrodes at sufficiently close intervals across the scalp. The figure above shows 19 labeled electrode positions having 20% spacing along standard lines of measurement, plus additional electrodes, FPZ and OZ, having 10% separation from nearest neighbors along a coronal line (FP1 and FP2 are the nearest 10% neighbors to FPZ, and O1 and O2 are nearest to OZ). The 20% interval separates nearest neighboring electrodes by 5-7cm in adults.

Although this is usually adequate for routine EEG, more precise localization, as needed in topographic mapping or delineation of epileptogenic foci, requires placing intermediate electrodes to reduce spacing to 10%, or about 3cm.

Electrode Application. Because *NuAmps* amplifiers are true DC amplifiers, you will find there are some differences in the application of electrodes.

- If you are using gold electrodes, they must be presoaked in water for about 2 hours before use.

- Do NOT mix metals across electrodes, e.g., do not use silver electrodes for the active channels and gold electrodes for the reference(s).

- Do NOT use one type of conductant at some sites, and a different type at other sites.

- Do NOT vary the skin-electrode interface, that is, if some of the electrodes do not actually touch the scalp/skin, as is the case with electrode caps having recessed electrodes, then all electrodes must be off of the scalp/skin. In the case with caps, this is done by placing a double-sided circle or V-shaped strips of tape between the electrode and skin for the reference(s) and EOG leads. The tape will also help hold the electrodes in place.

Failure to follow these directions can create DC battery potentials, which may, in turn, lead to clipping of the signals or complete saturation of the channels. The EEG will be either distorted or lost completely.

When using individual electrodes. Prior to placing an electrode, the scalp must be prepared by rubbing it vigorously with alcohol or a skin preparing agent. This removes dirt and oil from the electrode site and lowers the impedance. Obviously, excessive cleaning can be irritating to the patient. Similarly, some patients are sensitive to application of paste containing salt solutions or bentonite. Several varieties of electrode attachment media are available, including sodium chloride pastes or gels, conducting sponges, and other specialized electrolytes. Electrodes may be held in place by viscous gels, by mechanical restrictions (tapes, V-shape strips, bands or rubber caps), or by collodion.

If you use an abrasive paste, it is recommended that you use it on all sites. With DC amplifiers, it is important to treat all of the electrode contacts the same. The same type of electrodes (metal), the same conductant, and the same interface should be used with all electrodes. Mixing metals, or conductants, or skin/scalp interfaces can create DC battery potentials that may then lead to clipping or saturation and loss of EEG signals.

For prolonged recording, collodion is a glue formulated from pyroxylin in ether, alcohol, or camphor; it is liquid when applied, but dries to a strong adhesive within minutes. It is suitable for patients who cannot keep still, or who will need electrodes in place for more than a few hours. Pyroxylin is an element of gunpowder, and ether is highly flammable. Neither flame, nor excessive heat, nor pure oxygen should be in the vicinity of collodion applications. One must remember that collodion is not an adequate conductive medium (do not let it get between the electrode and the scalp). Conductive gel must be injected into the cup electrodes and refreshed periodically. A blunt needle is usually employed for this task. Collodion is removed with acetone scrubs.

With *NuAmps*, you MUST place the GROUND electrode first, then place the REFERENCE electrode(s) in order to see valid impedances as other electrodes are attached. Pay particular attention to attaching the ground and reference electrodes - attach them as securely as possible. Then place the active EEG electrodes.

Typically, after placing the GROUND and REFERENCE(S), you would place the CZ electrode next. Measure the distance between the Inion and Nasion using a measuring tape (in cm's). Calculate half that distance. Then measure from just in front of one ear to the same place in front of the other ear (positioning the tape over the top of the head). Ask the patient to open and close his mouth - the "dent" you feel in front of the ear is the point to take the measurements from. Calculate half of that distance. The intersection between those two imaginary lines - the half way point of each - is the location of CZ. The other placements are based on percentages (usually 10% or 20%, hence the 10-20 system) of those measurements. For example, O1 is 10% up from the Inion, and 10% over to the left. (If you use a wax pencil to mark the locations, be sure to remove the wax when you scrub the area. Wax is not a good conductor and the impedances could be affected).

P3 is 30% up from the Inion, and 20% over to the left. T7 is 10% up from the left ear measuring point (on a line through CZ). C3 is halfway between T7 and CZ. P7 is halfway between T7 and O1, and so forth.

The X3 electrode (for example) is placed above the left eye (VEOU), directly above the pupil (looking forward), and between the eye brow and Fp1. X4 (VEOL) is placed on the skin directly below the pupil, on the cheek bone, about 2cm below the eye. It is typically not necessary to place VEOG electrodes for both eyes, since the activity from the eyes is highly correlated. X1 (HEOL) may be placed about 2cm to the left of the left eye outer canthus (corner of the eye. X2 (HEOR) is placed about 2cm to the right of the right eye outer canthus.

After the recording, clean the electrodes gently, taking care not to scratch or pit the electrode surface. This can also lead to DC problems. Disinfect the electrodes according to safety protocols established in your facility. For example, soak the electrodes in a disinfecting solution (such as Abcocide, Metricide, or Betadine) in a concentration of 1 part disinfectant to 4 parts water, for 15-30 minutes, then dry them before the next use. If full strength disinfectant is desired, the electrodes should not be left in solution for more than 10 minutes.

For maximum electrode life, do not expose reusable surface electrodes to prolonged soaking or to cleaning with corrosive agents or bleach.

NOTE: electrodes should be cleaned and disinfected, but not sterilized because they are used externally.

Neuroscan recommends that you inspect electrodes for extensive wear or damage prior the use. If the electrode wire, termination, or surface area is worn so as to impair performance, the electrode should be discarded. Neuroscan is not responsible for injury, infection, or other damage resulting from improper electrode preparation or use.

When using electrode caps. To apply the reference electrodes to A1 and A2, for example, first clean the ear lobes with an alcohol prep pad, and let the alcohol evaporate. If you then use a preparation paste, gently scrub the area with that. In this case, you should use the same paste at all of the electrode sites. With electrode caps, this can be accomplished by using the wooden end of a Q-tip that is dipped in the paste, inserted through the electrode hole, and then gently rubbed on the scalp. The purpose is to make sure that the chemicals that are present between the electrodes and the skin/scalp are the same at all channels (to avoid potential DC battery potentials). If you find that your particular paste does not affect DC levels, you can safely ignore this precaution.

Place either a double-sided circle or V-shaped strip of tape on the earlobe or skin surface, and then place the reference electrode(s) on the tape. Inject the conductant, as described below, using a gently abrasive movement with the blunt syringe tip on the earlobe. Adding a piece of surgical tape over the top of the electrode and around the ear lobe will also help hold it in place. (If you need to add more gel, you can carefully poke the syringe through the tape). Attach any other loose EOG electrodes in the same fashion.

Quik-Cap Application. Your Quik-Cap has been designed with a highly elastic fabric that provides a uniform fit over a wide range of head size and shape variability. Quik-Caps currently use silver/silver chloride electrodes (gold and sintered silver are other options). The electrodes are carried in soft rubber holders for added wearer comfort.

When donning the cap, locate it loosely on the head after positioning the earlobe or mastoid electrodes first, using recommended skin preparation and electrolyte application techniques. Next pull the cap down firmly over the head, attach the chinstrap and ensure that the FP1 and FP2 electrodes are approximately 4cm above an imaginary line extended out from the Nasion. Also, check that the rear of the cap is stretched down the neck while holding the front of the cap in place, and then tighten the chinstrap slightly to fix the cap. Finally, place the VEOG monitoring electrodes, as described above for individual electrode placements.

Now that the cap is positioned, attach the wiring with tape or other fastening means (such as a Velcro® strap) onto the shoulder of the wearer. Ensure that there is adequate slack in the cable to allow head movement without pulling the cable. The final step is to insert a blunted syringe through the hole in each electrode down to the scalp surface. Lightly rock the syringe while moving it in a circular fashion and inject a small amount of EEG electrolyte. Make sure that you lift the syringe while injecting the electrolyte to guarantee that there is an unbroken path of electrolyte through the hair to the electrode disk (with no air bubbles). Be sure not to inject too much electrolyte because this could cause neighboring electrodes to be shorted together. Fill all electrodes in the cap before measuring impedances at any site except for the reference location(s) to allow the impedance values to stabilize. In order to minimize the amount of skin abrasion and increase the comfort of the wearer, we recommend using Quik-Gel EEG electrolyte with all cap systems. (NOTE: DO NOT COMBINE OTHER TYPES OF ELECTRODE MATERIALS OR USE MORE THAN ONE TYPE OF ELECTROLYTE WHEN USING THE QUIK-CAP.)

Using Quik-Gel. Quik-Gel is unique in its formulation and requires a few simple techniques to reduce your EEG electrode application time. Quik-Gel can absorb moisture from the scalp's dead skin barrier to rapidly lower electrode impedance. Therefore, little or no skin abrading is necessary to attain the same result as with other brands of EEG electrolyte.

Follow accepted selection and preparation techniques for reference, ground and EOG electrode locations. Inject a small amount of Quik-Gel into each electrode cup and apply to the skin using normal methods, being careful not to bridge the electrolyte between neighboring electrodes. For application into thick hair, press firmly on the electrode housing, insert the syringe tip and gently abrade as mentioned above. Note the following tips.

- Ensure that the syringe tip is lifted through the hair while Quik-Gel is being injected in order to ensure an unbroken contact between the scalp and electrode surface (with no air pockets).

- Apply electrolyte to all electrodes before measuring electrode impedance. In this manner, Quik-Gel will work to reduce the input impedance to acceptable levels necessitating less skin abrasion and patient discomfort.

- Use an elastic gauze size 4, 5 or 6 to cover the cap. You will find a more uniform pressure of the electrodes and a more stable impedance reading.

- When exposed to air, Quik-Gel will begin to crystallize. Place a glass of water next to your installation and when the syringe is not in use place the tip in the glass.

- KEEP CONTAINER TIGHTLY CLOSED WHEN NOT IN USE

- Do NOT refrigerate Quik-Gel.

- Distilled water can be used to thin the mixture. Be sure to shake well to ensure uniform consistency.

Impedance testing. The steps to follow have been described above, and only the main points to remember are repeated here. When using individual electrodes, you MUST *securely* place the GROUND electrode first, and then the REFERENCE(S) in order to see valid impedances. Pay particular attention to the ground and reference electrodes.

If you are using Quik-Gel, it is a good idea to place all of the electrodes first before looking at the impedances. Quik-Gel minimizes the amount of abrading that is necessary when you allow it to soak in for a few minutes.

Impedances may be read directly from the Impedance display, and they should be equal to or less than 10kOhms. They can also be read from the display on the face of the amplifiers. The ground impedance is not displayed, but the reference impedance is, and you should get the reference impedance(s) as low as possible. If they are high, all of the channels will be high. *NuAmps* will record with impedances up to 200kOhms (although the higher the impedance, the greater the likelihood of noise on the recording).

Quik-Cap Cleaning and Disinfecting Instructions. The following method is recommended for cleaning and disinfecting your Quik-Cap. After each use, remove all tape, markers, and electrode pads from the cap and unhook any wire harness shoulder restraint. Unplug the wire harness from the amplifier equipment and remove the cap from the wearer. Take the cap to a sink and rinse off any electrolyte on the outside of the cap and electrodes. Next, turn the cap inside out to expose the electrodes that are down inside the rubber holders. Run a tight stream of very warm or hot water from the faucet and use it like a drill to remove the electrolyte from the holder cavity. This should remove the electrolyte completely if you are using Quik-Gel, if not, and the electrolyte has oils in it (like ECI-Gel), you will need to use cotton swabs to help remove the electrolyte residue from the electrode surface while the water is running. Do this carefully to avoid scratching or pitting the surface of the electrodes. Next, turn the cap back out and use the water to remove any additional electrolyte from the outside of the cap.

When you are satisfied that nearly all electrolyte has been removed, place the cap and wire harness into a warm water and soap bath being careful not to get the connector at the end of the harness wet. The bath should contain 4 quarts of water with 1 or 2 ounces of mild dish soap (IvoryTM, DoveTM, etc.). Let the Quik-Cap sit in the bath for approximately 1/2 hour. Remove and rinse the Quik-Cap with warm water and place it into a disinfecting solution (such as Abcocide, Metricide, or Betadine) in a concentration of 1 part disinfectant to 4 parts water. If this disinfectant method is selected, leave the cap in the solution for 15 to 30 minutes. If full strength disinfectant is desired, the cap should not be left in solution for more than 10 minutes. After disinfectant, rinse the cap thoroughly and hang it up to dry. For faster drying, the cap can be set in front of a fan, however, direct heat sources should not be used to dry the cap.

(Note: compressed air can be used to blow moisture from the electrodes and wire entry points and is very useful for extending the life of your Quik-Cap).

14 Appendix C: PocketTrace-2 Signal Generator

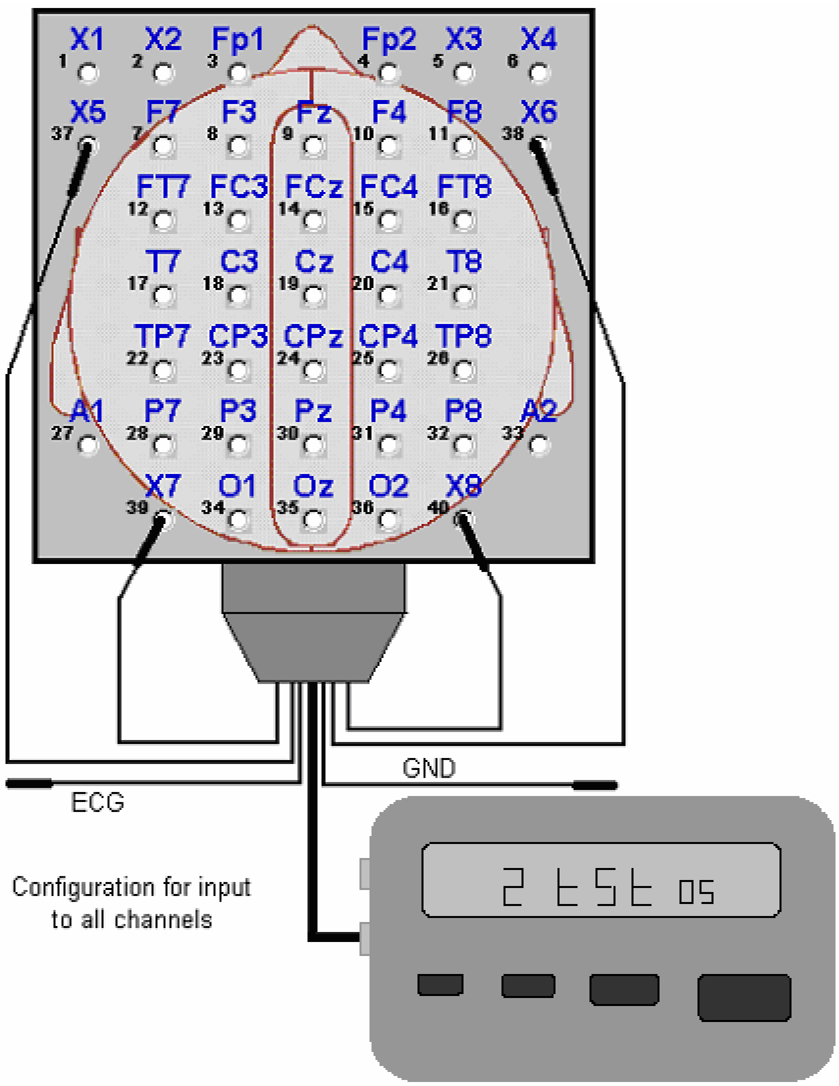
The PocketTrace and PocketTrace-2 (PT-2) units are small and extremely useful devices for generating signals that may be sent to the *NuAmps* or other EEG/ECG amplifiers. The signals can be used for calibrating the system, and as a means to test the basic functionality of the system without having a live subject connected. Together with the PT-2 Adapter, which has attenuators from 2000:1 to 20000:1, the device will produce a variety of signals with varying frequencies and amplitudes (within the physiologically normal range for EEG and ECG). A TTL pulse is generated with each repeated signal to test trigger functions.

PT-2 is a modified version of the original PT-1 model. PT-2 has 4 control buttons (rather than three in the PT-1 model), as shown on the picture below. It provides the same functionality as PT-1, with better precision (±1.2% instead of ±3.5%), but is controlled differently and has additional information on the LCD. If you need information for the PT-1 device, please contact techsup@neuroscan.com. The information below is for PT-2.

Note: When using PT-2 in ACQUIRE, you must set the Reference to Virtual Ground. (From the *NuAmps* Setup Editor, click the Edit button, *NuAmps* Setup, then select the Reference tab, and the select the Virtual Ground option). Return the Reference option to your original choice when you are finished with PT-2.

Cable Connections Please refer to the diagram on the next page showing the PocketTrace connected to the *NuAmps* amplifiers. In this configuration, the signal from PocketTrace will be sent to all channels in *NuAmps*.

Connecting the cable(s) to *NuAmps*. The supplied cables have a large connector on one end (DSUB37-M connector), and 7 cables coming out from the back of the large connector. Six of the wires end in touch-proof connectors. One is labeled GND (ground), one is labeled ECG (electrocardiogram), and the other 4 are not labeled. The seventh wire is longer and larger, and it ends in a mini-phone connector. You can take the output from PocketTrace and send it through all the channels, or you can selectively choose up to 5 input channels.

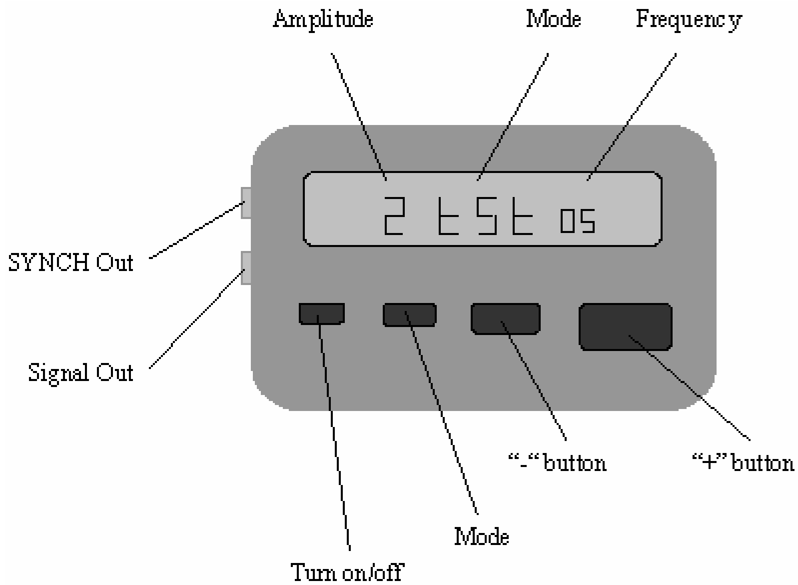


Sending the signal to all channels. To send the signal generated by PocketTrace to all channels, simply plug the large connector into the CAP connector on the *NuAmps* amplifiers. Then connect the longer (and larger) wire into the SIGNAL Output jack on the side of PocketTrace, and connect the smaller, loose wires as shown in the diagram.

Sending the signals to selected channels. Connect the GND lead to either GND jack on the amplifier unit. The ECG lead differs from the 4 unlabeled channels in that its output has a much larger amplitude. Plug it into any desired channel. Plug the remaining leads into any other desired channels. Connect the longer (and larger) wire into the SIGNAL Output jack on the side of PocketTrace. Do NOT connect the large connector to the CAP connector on the side of the *NuAmps* amplifiers.

Connecting the TTL pulse cable (optional). With some of the Modes (described below), a TTL pulse is sent out through the SYNCH Output jack. This is used to simulate trigger inputs into *NuAmps* (or other device). The output is a positive logic (resting at 0Vs), TTL compatible (5V) pulse with a 10ms duration. This feature currently has no use with *NuAmps* systems (as TTL pulse triggering has not currently been implemented), and should be ignored.

Operations. The follow information explains the basic operations of PocketTrace.



Turning the device on/off. Press the left-most button (with the red dot) to turn on the device. Press the same button again to turn it off. The device will turn off automatically if you do not press any button for 10 minutes. If you press the "+" button and then turn on the device, it will operate until the battery is discharged, or until you turn it off. With this mode of operation, the "globe" symbol is shown in the right upper corner.

Blinking indicator. If the LCD blinks, you need to change battery.

Signal type selection. Use the "Mode" button to change the type of generated signal.

Selecting the frequency of the output signal. The Increase (+) and Decrease (-) buttons are used to change the *frequency* of the output signal. This frequency is shown on the right field of LCD. A single press of the Increase button will increase the frequency by one step. If this button is pressed for several seconds, the frequency will increase rapidly and continuously. The Decrease button operates in same way to decrease the frequency.

Selecting the amplitude of the output signal. To increase the amplitude, press the "+" button and while keeping it pressed, press the "Mode" button. To decrease the amplitude use the "-" and "Mode" buttons. The amplitude of the output signal is indicated by the symbol to the left of the signal type. The device provides 3 amplitudes:

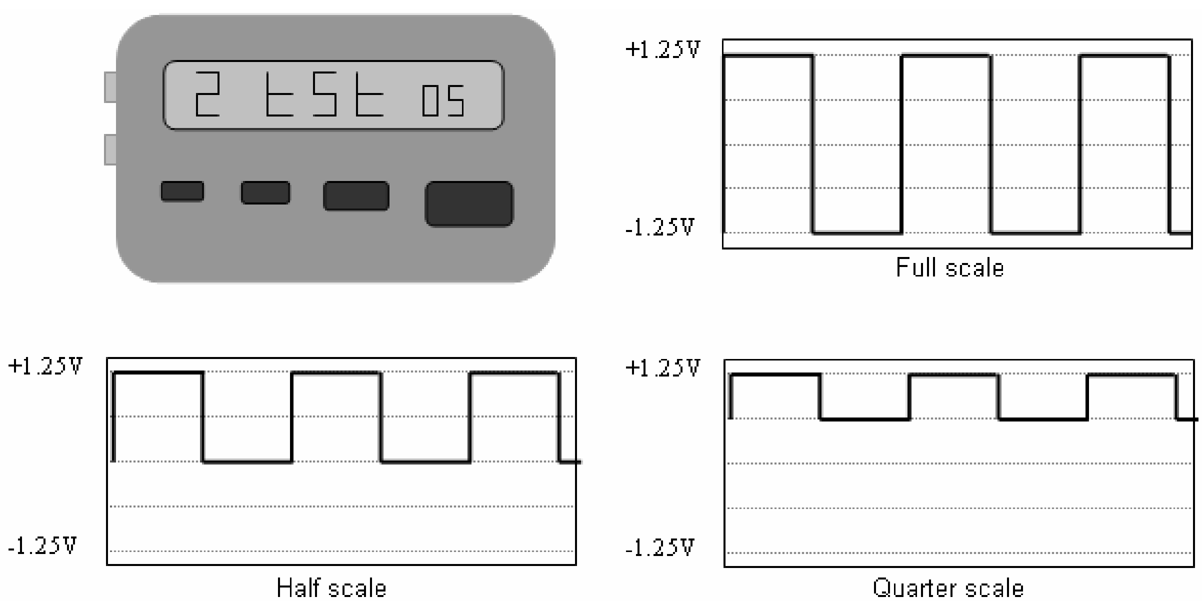
Full scale (±1.25V ±1.2%) – no symbol at the left is shown
Half of scale (±0.65V ±1.2%) – symbol at the left is "1"
Quarter of scale (±0.31V ±1.2%) – symbol at the left is "2"

Amplitude Indicator	DC shift
None	-1.23V, ±3.5%
1	0V, ±45mV
2	+1.23V±3.5%

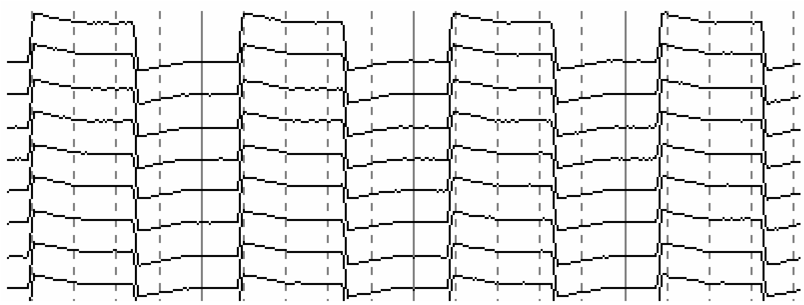
With the half-scale and quarter-scale modes, the signal has DC components. In "Square pulses" mode with a frequency setting of 0Hz (described below), the signal amplitude is 0, and the DC component varies as shown:

Signal output jacks. The signals from all modes in PocketTrace are sent out from the SIGNAL Output jack on the side of the device. With some modes, TTL pulses (positive logic, voltage pulses) are sent out from the SYNCH Output jack on the side of the unit.**Operational modes.** There are 6 different operational modes: a square wave generator, a sine wave generator, 3 visual evoked response simulations, and an ECG simulation.

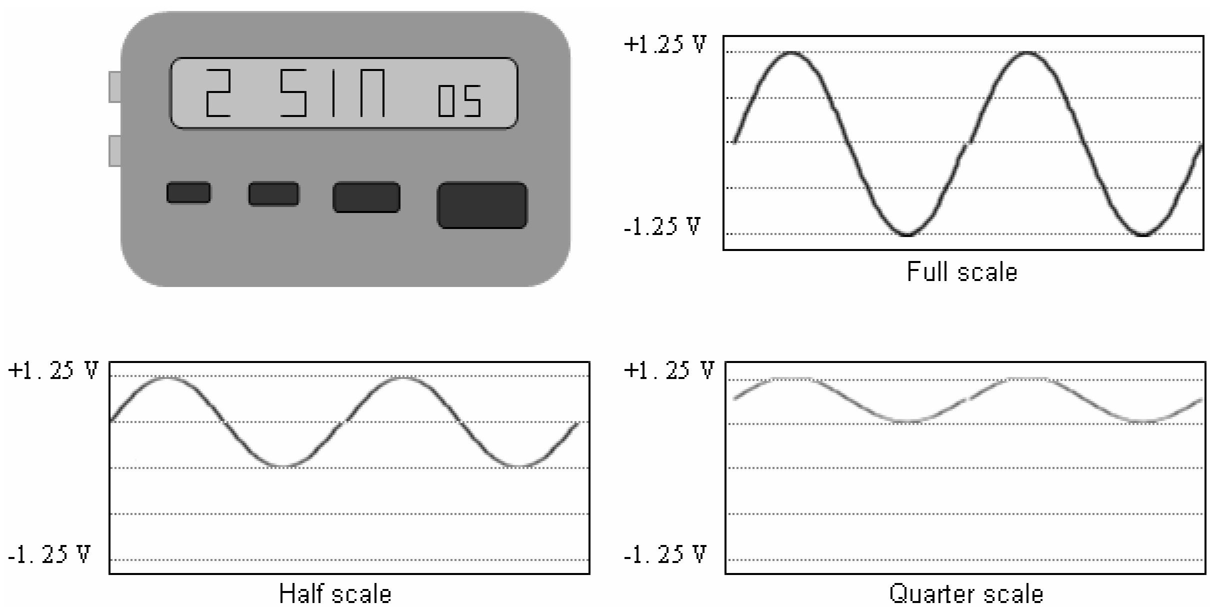
“Square pulses” mode. In this mode the device produces rectangular square wave pulses in a frequency range of 0.5-99Hz.



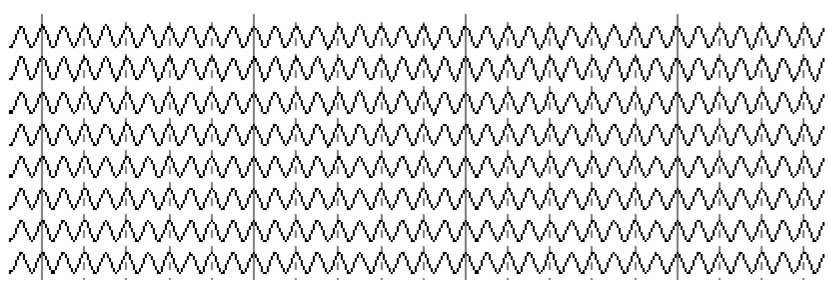
In ACQUIRE, you will see signals similar to the following (High and Low Pass filters OFF):



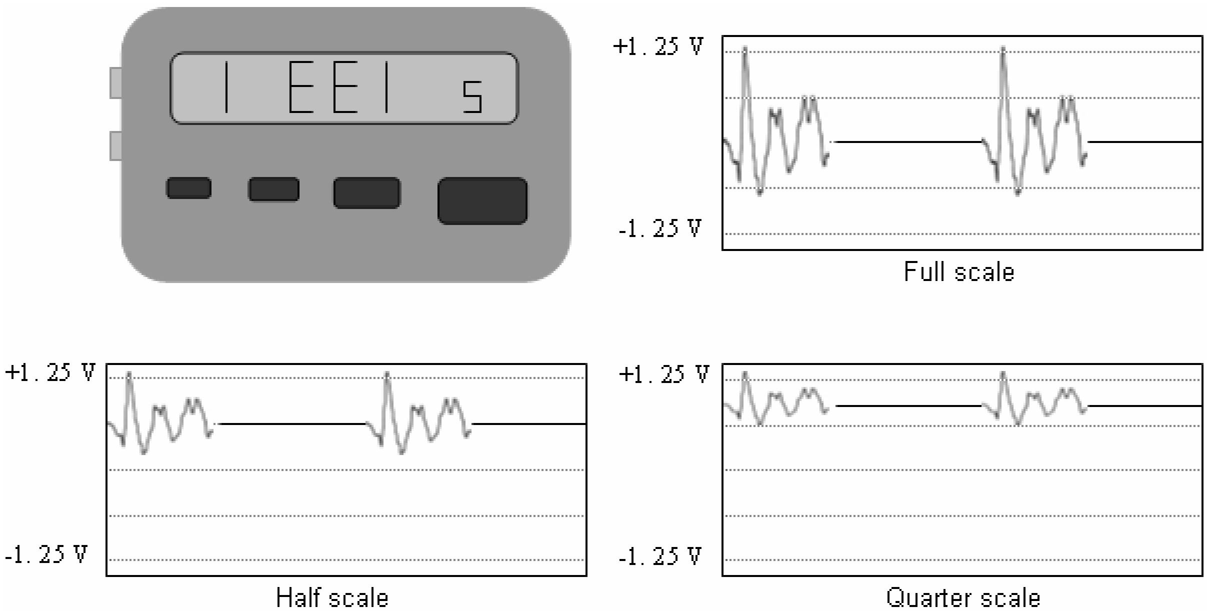
"Sinusoidal signal" mode. This mode is used to generate a sinusoidal signal in the 0.5-90Hz frequency range.



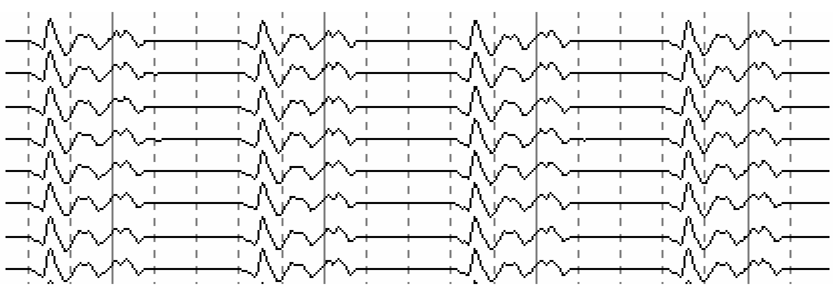
In ACQUIRE, the signals will look similar to the following:



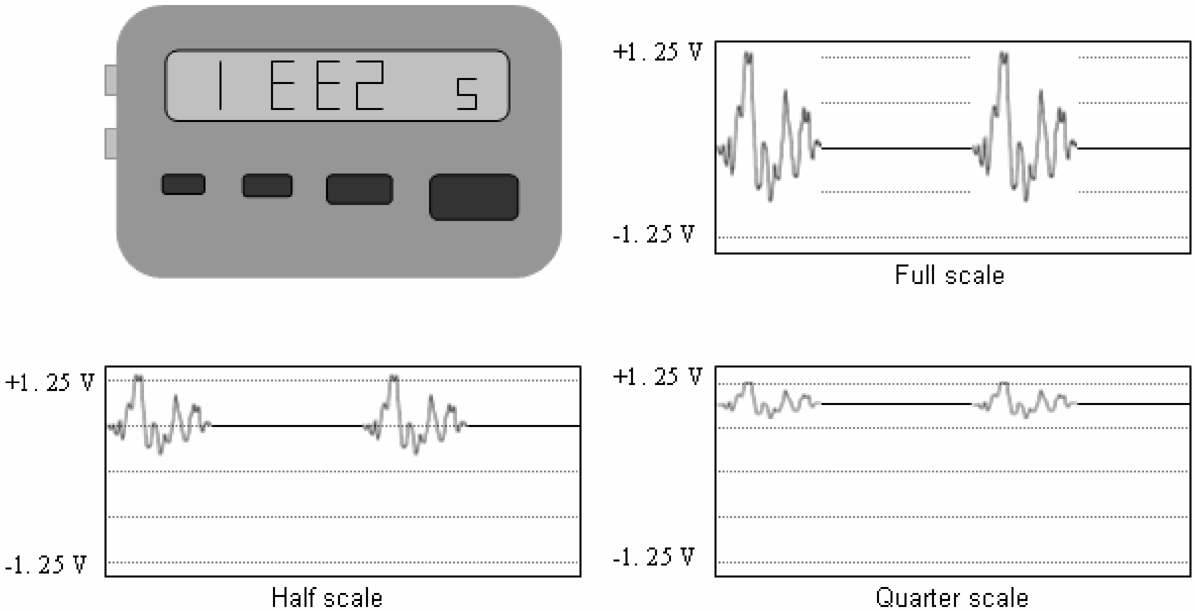
"Special wave-EE1" mode. In this mode the device produces a simulated visual evoked response to a *checkerboard reversal* pattern. The signal consists of a series of impulses, which appear with a frequency range from 0.5 to 1.6Hz. A new impulse can be generated even if the previous impulse has not finished (the impulses may overlap). Simultaneously, with every new impulse generation, a TTL trigger pulse (positive logic) is sent from the SYNCH jack. *Note: the frequency of impulses is expressed in Hz times 10 (for example, display "15" corresponds to 1.5Hz).*



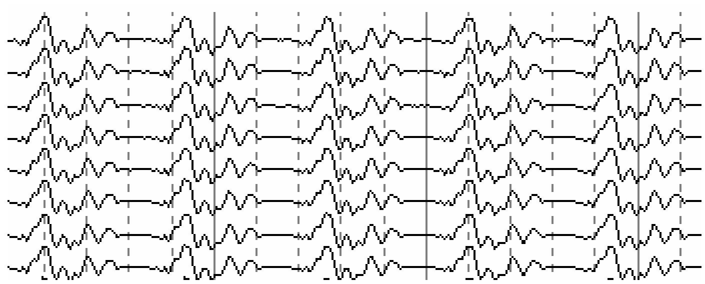
In ACQUIRE, the signals will look similar to the following:



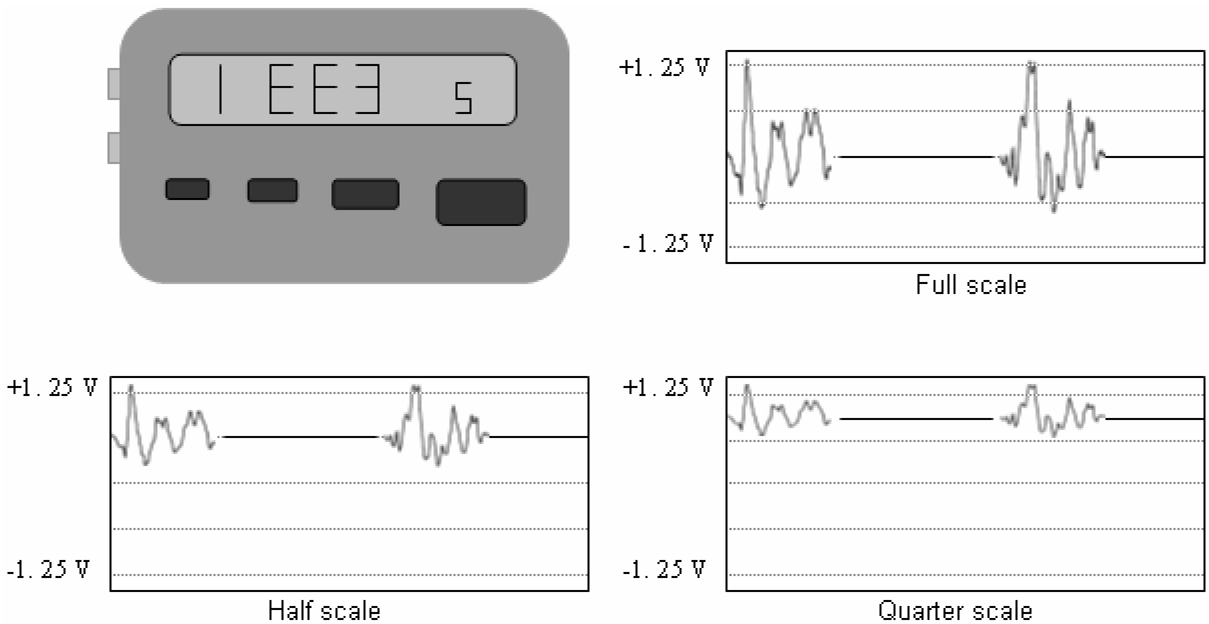
“Special wave-EE2” mode. In this mode the device simulates a visual evoked response to *flash* stimulation. The signal consists of a series of impulses in the frequency range of 0.5-1.6Hz. A new impulse can be generated even if the previous impulse has not finished (the impulses may overlap). Simultaneously, with every new impulse generation, a TTL trigger pulse (positive logic) is sent from the SYNCH Output jack. *Note: the frequency of impulses is expressed in Hz times 10 (for example, display “15” corresponds to 1.5Hz).*



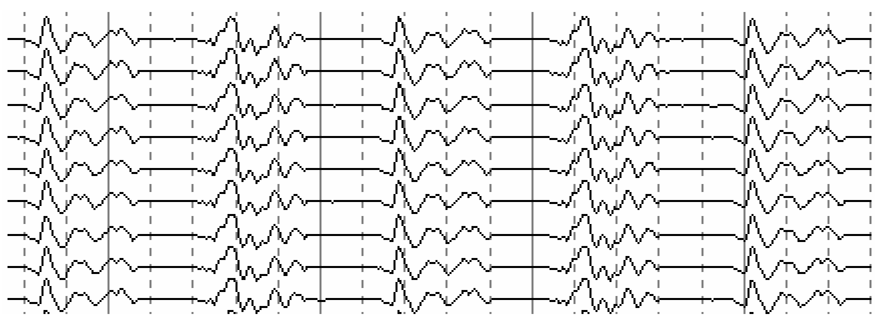
In ACQUIRE the signals will look similar to the following:



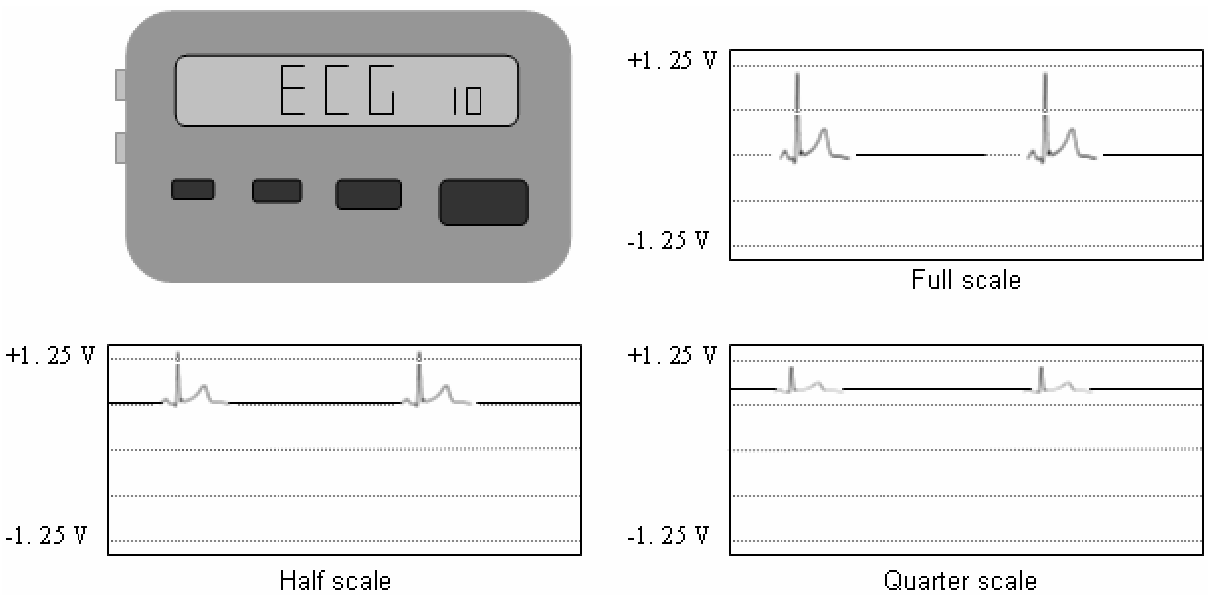
“Special wave-EE3” mode. In this mode the device produces alternating “special wave-1” and “special wave-2” signals from the SIGNAL Output jack. The signals have a frequency 0.5-1.6Hz. *Note: the frequency of impulses is expressed in Hz times 10 (for example, display “15” corresponds to 1.5Hz).*



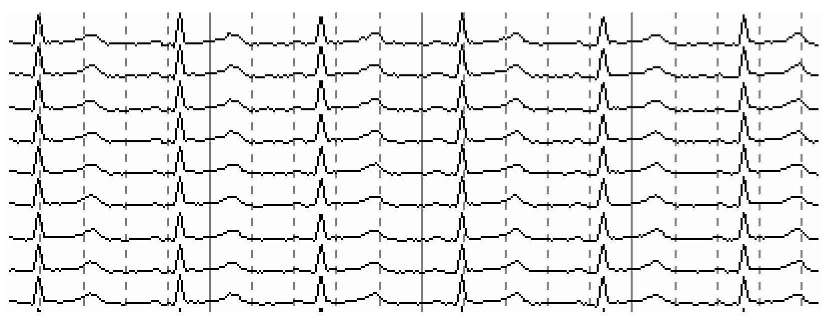
In ACQUIRE, the signals will appear similar to the following display:



ECG Mode. This mode simulates ECG activity. The waveforms appear within a frequency range of 0.5 to 1.6Hz, with three amplitude levels. Simultaneously, with every new impulse generation, a TTL trigger pulse (positive logic) is sent from the SYNCH output jack.



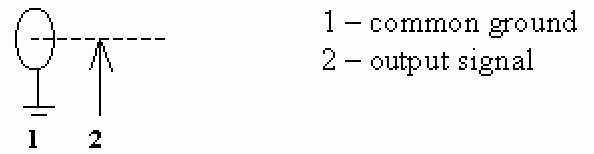
In ACQUIRE, the signals will look similar to the following:



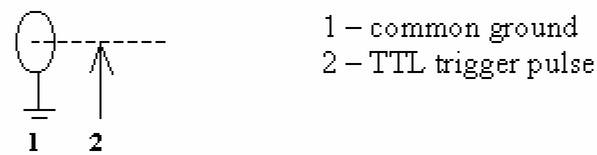
Technical specifications

Description	Value
Peak-to-peak signal voltage on SIGNAL output	±1.23 (0.62,0.31) V±3.5%
Relative error of signal frequency	Not more than 0.5%
Output impedance for SIGNAL output	Not more than 100 Ohm
Synchro-pulse level on SYNCH output	TTL compatible
Duration of synchro-pulse	10 ms ±10%
Power supply	One AAA-size battery
Duration of operation for one battery ("Alkaline" type)	Not less than 45 hours

Pin-out of SIGNAL connector

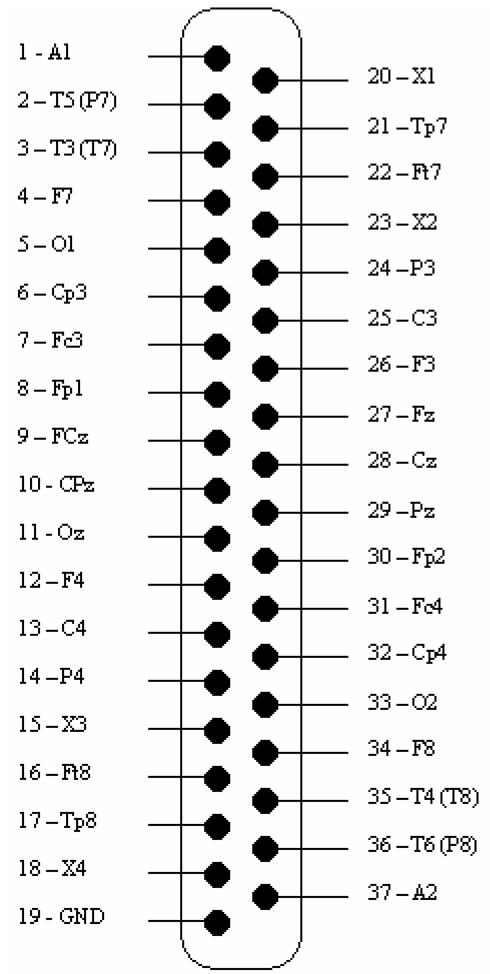


Pin-out of SYNCH connector



15 Appendix D: Cap Connector Pinout

The pinout for the cap connector is as shown:



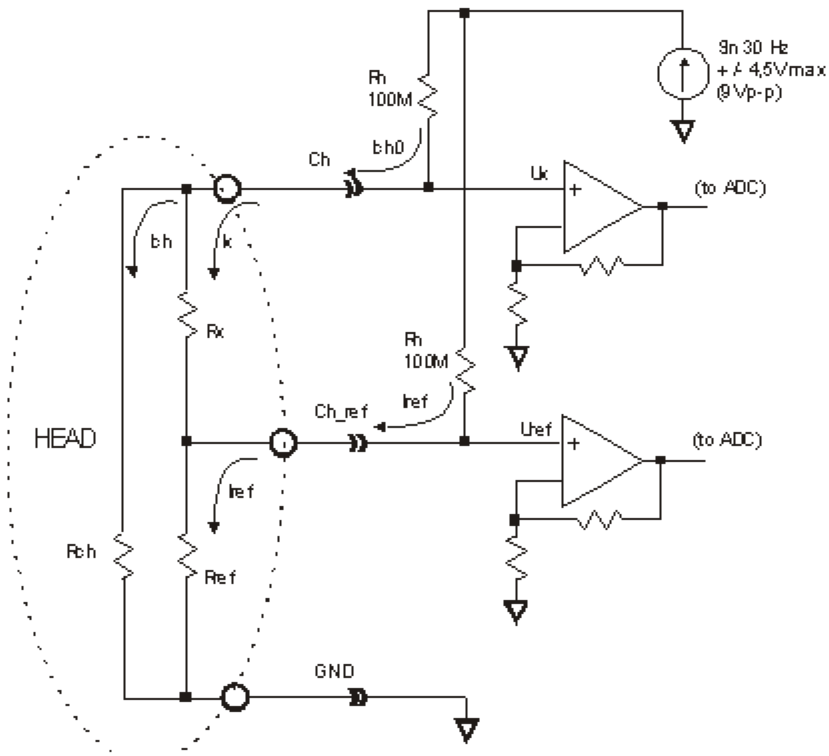
X5 (FT9), X6 (FT10), X7 (PO1), X8 (PO2) electrodes are not wired to DSUB37 but can be accessed through front-panel individual touch-proof connector.

16 Appendix E: Impedance Measurement

The following section explains how *NuAmps* conducts impedance measurement.

Scheme of input cascades during impedance measurement

The picture below depicts impedance measurement on a subject's head (outline by dashed circle) with 3 electrodes attached – active (**Ch**), reference (**Ch_ref**) and ground (**GND**) electrodes:



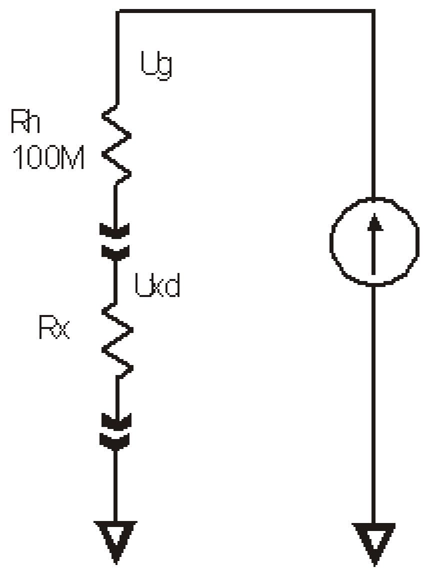
A 30Hz sine signal is injected to the head at all channels, including the reference, through their 100MOhm input resistors. As a result, each electrode injects a 30Hz harmonic current with 45nA maximum amplitude (4.5V / 100MOhm). Current from all channels flows back to the amplifier through the GND electrode. Therefore, the maximum summary current through GND is equal to the number of active electrodes, plus one reference electrode, multiplied by 45nA.

Denote the current injected through the **Ch** active channel as **Ich0**. This current splits into 2 parts: **Ich0 = Ich + Ix**, where **Ix** is the current through an unknown **Rx**.

Ch can be any channel and **Ch_ref** is the reference channel selected for impedance measuring. Impedance is measured and calculated between **Ch_ref** and the other channels. No special commutation circuitry is used for **Ch_ref**. It is specified by the software and may be any channel. Usage of **Ch_ref** also minimizes the effect of multiple current sources and better blocks the common-mode voltages (by measuring Ux-Uref).

Equivalent scheme for transhead impedance calculation

As impedance inside the head is distributed, finding **Rx** in the case of many active electrodes is a very complicated mathematical problem. Consider the simplified equivalent schematic, where **Rref** =const=0. As a result, **Rch** transforms to **Rx**:



According to this schematic:	Uxd/Rx = Ug/(Rh+Rx)
After reorganization:	Rx = Rh*Uxd/(Ug-Uxd)
As Ug>>Uxd:	Rx = Rh*Uxd /Ug (1)

Where Uxd = (Ux – Uref) is voltage difference between **Ch** and **Ch_ref** .

Algorithm of the transhead impedance calculation

The next algorithm is implemented for impedance measurement and calculation:

1. Voltage (Ux-Ured) is measured and filtered by 28-32Hz (-3dB) pass-band filter (8 order IIR Butterworth);
2. SQR value of (Ux–Uref) is calculated for a 1 sec interval;
3. Impedance **Rx** is calculated once per second according formula (1).

This is repeated for all channels.