Experiment HN-3: Human Nerve Conduction

Background

Each nerve fiber in a nerve is capable of generating an action potential which can be propagated along its length without any loss of amplitude or velocity. Nerve fibers that have large diameters, and are covered with the insulation of a myelin sheath, conduct impulses down their length with the highest velocities. The motor-neurons that supply skeletal muscles are included in this category. Small unmyelinated nerve fibers, like the sensory fibers originating in digestive organs, are the slowest neurons in the body.

When the motor and sensory neurons that are bundled together to create nerves are stimulated, the nerve produces a compound action potential (CAP), which is the summation of the action potentials from nerve fibers that are activated by the stimulus. As the strength of the stimulus is increased, more fibers in the nerve are recruited and the amplitude of the compound action potential is greater. The conduction velocity of the compound action potential is also related to the composition of the nerve; nerves with a greater number of large myelinated neurons have higher relative conduction velocities.

Conduction velocities are often used to measure the relative health of the nervous system. A disease that affects the nervous system by damaging myelin sheaths, or destroying membranes and membrane transport, or constricting nerves can be indicated by changes in nerve conduction velocity (NCV) of the patient. NCV tests are performed when the following diseases or conditions are suspected: carpal tunnel syndrome, traumatic damage, poliomyelitis, diabetic neuropathy, chronic inflammatory polyneuropathy, and Guillain-Barre syndrome.

In this experiment, the ulnar nerve of a subject will be stimulated and the response of a muscle innervated by the nerve will be recorded as an indicator of nerve activity. Three aspects of nerve activity will be studied in this experiment: the relationship between stimulus strength and the amplitude of the nerve/muscle response; the latency of the nerve as a function of the polarity of the stimulus pulse; and the nerve conduction velocity. To measure nerve conduction velocity, the nerve will be stimulated at two different points along its length. Because the distance between the two stimulation points and time difference between muscle responses from those two positions can be measured, the nerve conduction velocity can be calculated.

The stimuli that stimulate the nerve and evoke the response recorded from the muscle will be generated by the iWorx SI-200 stimulus isolation unit. This unit will be programmed to provide mild electrical shocks to the nerve through the skin. The electrical stimulation of the nerves in the forearm is safe; but, standard safety precautions need to be observed. People with poor cardiac function, pacemakers, or any other condition that can be aggravated by electrical stimulation should not volunteer for this experiment.

Equipment Required

- PC Computer
- IWX/214 data acquisition unit
- USB cable
- Power supply for IWX/214
- AAMI cable and three ECG/EEG/EMG lead wires
- Disposable snap electrodes
- SI-200 High voltage isolated stimulator
- Power supply for SI-200
- HV stimulator lead wires for SI-200
- BNC-BNC cable
- BNC-Banana adapter

IWX/214 Setup

1 Place the IWX/214 on the bench, close to the computer.

2 Check Figure T-1-1 in the Tutorial Chapter for the location of the USB port and the power socket on the IWX/214.

3 Check Figure T-1-2 in the Tutorial Chapter for a picture of the IWX/214 power supply.

4 Use the USB cable to connect the computer to the USB port on the rear panel of the IWX/214.

5 Plug the power supply for the IWX/214 into the electrical outlet. Insert the plug on the end of the power supply cable into the socket on the rear of the IWX/214. Use the power switch to turn on the unit. Confirm that the power light is on.

Start the Software

1 Click on the LabScribe shortcut on the computer's desktop to open the program. If a shortcut is not available, click on the Windows **Start menu**, move the cursor to **All Programs** and then to the listing for **iWorx**. Select **LabScribe** from the **iWorx submenu**. The LabScribe **Main window** will appear as the program is opens.

1 On the **Main window**, pull down the **Settings menu** and select **Load Group.**

2 Locate the folder that contains the settings group, **IPLMv4Standard.iwxgrp**. Select this group and click **Open**.

3 Pull down the **Settings menu**, again. Select the **Human-NerveConduction-LS2** settings file.

4 After a short time, LabScribe will appear on the computer screen as configured by the **HumanNerveConduction-LS2** settings.

5 For your information, the settings used to configure the LabScribe software and the IWX/214 unit for this experiment are listed in Figure HN-3-1 on page HN-3-2 and Table HN-3-2 on page HN-3-2. These settings are programmed on the **Preferences Dialog window** which can be viewed by selecting **Preferences** from the **Edit menu** on the LabScribe **Main window**.

Table HN-4-1: Settings on the Channel Window of the Preferences Dialog Used to Configure the iWorx Recording System for Experiment HN-3.

Parameter	Units/Title	Setting	Mode/ Function
Acquisition Mode		Chart	
Start		User	
Stop		User	
Display Time	Sec	5	
Speed	Samples/Sec	200	
Channel A3	Finger Twitch	√	DIN8
Channel S1	Stimulus Trigger	√	Record

Table HM-4-2: Settings on the Stimulator Window of the Preferences Dialog Used to Configure the Stimulator of the IWX/214 for Experiment HM-3.

Parameter	Setting	Parameter	Setting
Stimulator	Stim 1	Delay (sec)	0
Stimulus Mode	Pulse	Amplitude (V)	5
Start Stimulator with Recording	√	Pulses (#)	0
Time Resolution (msec)	0.01	Pulse Width (msec)	5
Toolbar Step Frequency	1	Frequency (Hz)	1
Toolbar Step Amplitude (V)	0.1	Time-Off Amplitude (V)	0
Toolbar Step Time (sec)	0.1	Holding Potential (V)	0

Equipment Setup

1 The subject should remove all jewelry from his/her right hand and wrist.

2 Clean the areas where the electrodes will be attached with an alcohol swab (Figure HN-3-1 on page HN-3-2). Abrade the skin in those areas.

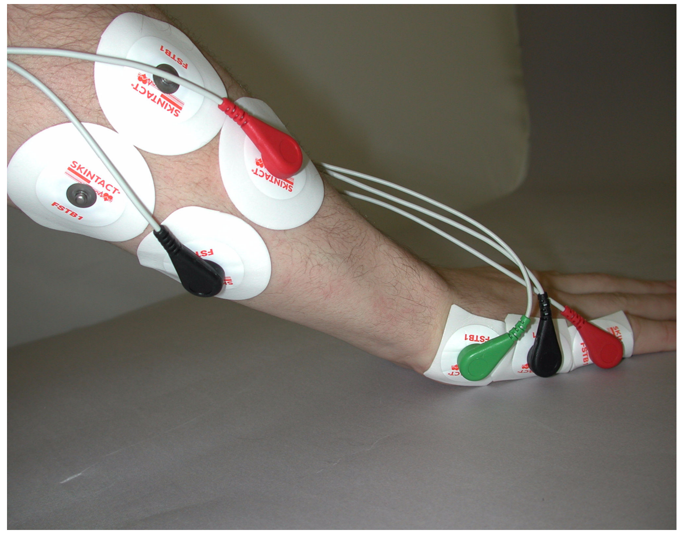

Figure HN-3-1: Placement of the recording, ground, and two pairs of stimulating electrodes on the lateral edge of the right hand and arm.

3 Obtain seven disposable electrodes.

4 Peel the protective shield off one of the electrodes and place it on the lateral edge of the little finger of the right hand, so the electrode button/snap is just above the first knuckle (Red (+) recording electrode in Figure HN-3-1 on page HN-3-2).

5 Attach six additional electrodes to the subject's right hand and arm so that they are placed in the following configuration:

- on the lateral edge of the palm, so the electrode button/snap is halfway between the base of the little finger and the wrist crease (Black (-) recording electrode on the hand in Figure HN-3-1 on page HN-3-2).
- so the electrode button/snap is on the lateral edge of the wrist at the crease (Green (G) electrode on the hand in Figure HN-3-1 on page HN-3-2).
- on the lateral edge of the forearm, so the electrode button/snap is 50-60 millimeters above the wrist crease (Black (-) stimulating electrode in Figure HN-3-1 on page HN-3-2).
- right next to the negative stimulating electrode towards the medial side of the forearm 50-60 millimeters above the wrist crease (Red (+) stimulating electrode in Figure HN-3-1 on page HN-3-2).
- on the lateral edge of the forearm 200 millimeters above the wrist crease (blank electrode in Figure HN-3-1 on page HN-3-2).
- right next to the negative stimulating electrode towards the medial side of the forearm 200 millimeters above the wrist crease (blank electrode in Figure HN-3-1 on page HN-3-2).

6 Attach the AAMI connector on the end of the gray patient cable to the isolated Channel 1 and 2 inputs of the iWorx recording unit (Figure HN-3-2 on page HN-3-3).

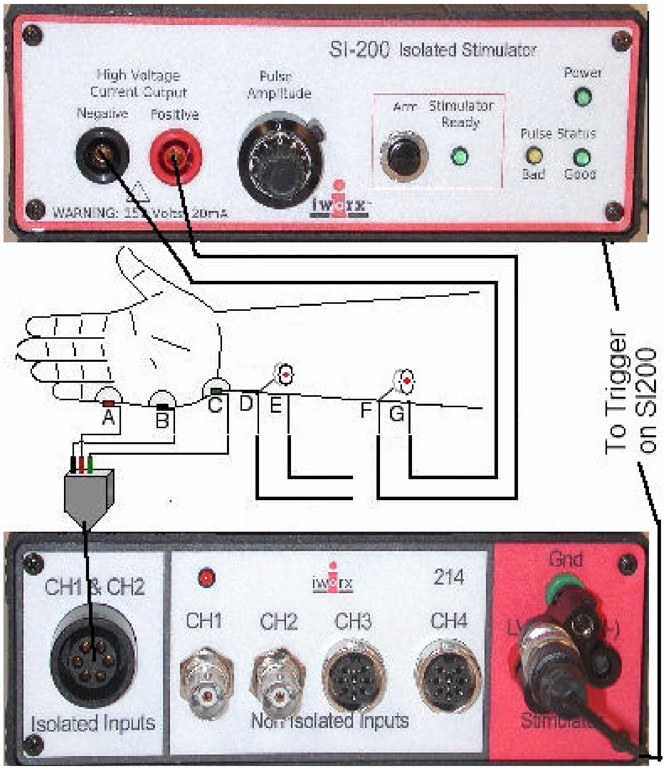

Figure HN-3-2: Equipment needed to stimulate the ulnar nerve and record the impulses from the abductor muscle of the little finger.

7 Attach three color-coded electrode cables to the ground and Channel 1 inputs on the lead pedestal and snap the other ends onto the disposable electrodes, so that (Figure HN-3-2 on page HN-3-3):

• the red "+1" lead is attached to the electrode (A) closest to the pinkie.

• the black "-1" lead is attached to the electrode (B) on the center of the side of the hand.

• the green "C" lead (C) is attached to the electrode near the wrist..

8 Place the SI-200 on the bench near the subject. Plug the cable of its power supply into the unit. Then, plug the power supply into the outlet. Turn the SI-200 on.

9 Attach one end of a BNC-BNC cable to the **Trigger** input on the back panel of the iWorx SI-200.

10 Connect the other end of this BNC-BNC cable to the output of IWX/214. The output of the A/D is used to activate the SI-200 and control the time parameters of the output of the SI-200 (Figure HN-3-2 on page HN-3-3):

• The BNC-BNC cable from the **Trigger** input of the SI-200 is connected to the stimulator output IWX/214 through a BNC-double banana adapter.

• The adapter is placed into the positive (red) and ground (green) banana jacks of the stimulator output. One side of adapter is labeled with an embossed tab (**GND**) indicating the connector on this side of the adapter is the ground. This side of the adapter should be placed in the green banana jack.

11 Connect the black (-) stimulating lead from the **Negative High Voltage Output** of the SI-200 to the electrode (D) on the lateral edge of the forearm 50-60mm above the wrist.

12 Connect the red (+) stimulating lead from the **Positive High Voltage Output** of the SI-200 to to the electrode (E) adjacent to the one on the lateral edge of the forearm 50-60mm above the wrist.

13 The "blank" electrodes (F and G) will be used when the nerve conduction velocity is determined.

Operating the SI-200

1 Check the amplitude, pulse width, frequency and number of pulses programmed into the stimulator that is controlling the SI-200. The pulse amplitude should be set to **5.0V**.

Warning: Make sure the stimulus amplitude knob of the SI-200 is set to zero.

2 Flip the power switch on the back of the SI-200 to the **On** (**I**) position. If the SI-200 is working properly, the **Power light** on the front of the isolated stimulator will glow.

3 Push the **Arm button** on the SI-200 to activate the output of the unit. The **Stimulator Ready light** next to **Arm button** will glow indicating that the isolated stimulator is ready to deliver a stimulus pulse.

4 Activate the recorder and the stimulator controlling the SI-200.

5 Slowly rotate the **Pulse Amplitude knob** clockwise **1 turn**, which is equal to a current output of **2 milliamperes** (**mA**). Ask the subject to indicate when he or she first feels a tingling sensation under the stimulating electrodes.

6 If no response is detected, the stimulus pulse amplitude is below the current level needed to create a response. The pulse amplitude required to cause a response will differ between subjects. Some subjects require as low as 6 milli-amperes of current to create a simple muscle twitch, while other subjects may require 10 or more milliamperes to create the strongest muscle twitch.

7 If a response does not occur at **2 mA** after 4 or 5 pulses, rotate the **Pulse Amplitude knob** an additional half turn to increase the stimulus current by **1 mA**. Stimulate for another 4 or 5 pulses. Ask the subject to indicate if tingling and a response is detected. Increase the current output in increments of **1 mA,** and record 4 or 5 pulses, until a detectable response occurs.

8 Follow the procedures specified in the experimental write-up.

Exercise 1: Stimulus Strength and Muscle Response.

Aim: To determine the effect of stimulus strength on the response of the innervated muscle.

Procedure

1 Ask the subject to place his or her right hand on the bench with the palm down. Tell the subject to relax.

Note: *The subject should make sure to relax his/her forearm and hand completely. Any tensing of the muscles would interfere with the recording.*

2 Set the **Amplitude** knob on the front panel of the SI-200 unit to zero.

3 Click **Record** button on the LabScribe **Main** window. LabScribe will record a single sweep with a display time of 50 milliseconds. Since the output amplitude of the SI-200 is set to zero, there should be no response from the abductor muscle.

4 Increase the output amplitude of the SI-200 by rotating the **Amplitude** knob one half turn to the **0.5** position which is equivalent to 1 mA. Click the **Record** button again and record another single sweep. Click the **AutoScale** button for the **Muscle** channel to improve the display of the muscle's response (Figure HN-3-3 on page HN-3-4).

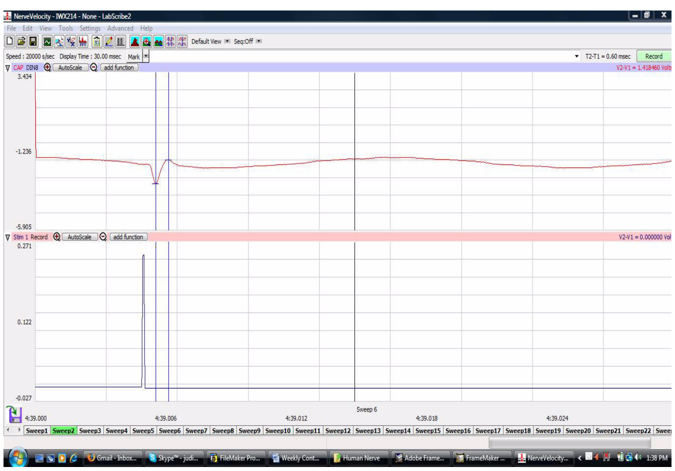

Figure HN-3-3: Muscle response of abductor muscle of the little finger to stimulation of the ulnar nerve.

5 Continue to increase the output amplitude of the SI-200 by rotating the amplitude knob one half turn at a time, each turn is an increment of **0.5**. A maximum of twenty is possible.

• Click the **Record** button to record a single sweep after each increase in the stimulus amplitude.

• Continue to increase the output amplitude and record the response until the muscle impulse reaches a maximum level.

6 Select **Save As** in the **File** menu, type a name for the file. Choose a destination on the computer in which to save the file(e.g. the **iWorx** or class folder). Click the **Save** button to save the file (as an ***.iwd** file).

Data Analysis

1 Click the **Analysis** icon in the LabScribe toolbar (Figure HN-3-4 on page HN-3-4) to view all the recorded sweeps.

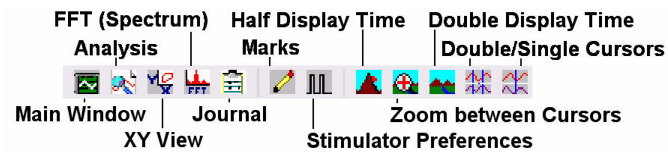

Figure HN-3-4: The LabScribe toolbar.

2 Use the Windows **control-click** function to select the sweeps of interest from the **Sweeps** list on thebottom of the **Analysis** window. For comparison, superimpose the selected sweeps on each other by clicking the sweeps of interest. See Figure HN-3-5 on page HN-3-4.

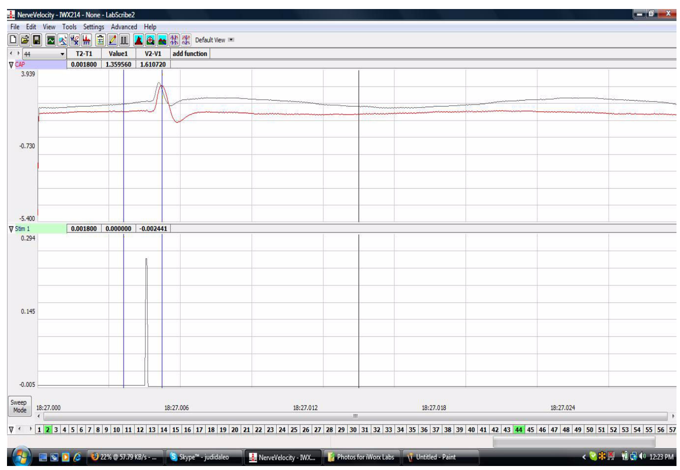

Figure HN-3-5: Comparison of muscle responses to different stimulus amplitudes. Sweeps are superimposed in the Analysis window. Values for sweep #44 are shown.

3 Select **Title** and **V2-V1** from the **Add Functions** list if they are not already listed.

4 Go to the **Sweep List** at the top of the **Analysis Window** and select the sweep that has the lowest muscle response. Selecting a sweep from this menu will display the measured values of that sweep in the table at the top of the **Analysis** window.

5 Click the **2-Cursor** icon in the LabScribe toolbar. Drag one cursor to the left of the stimulus artifact and the second cursor to the peak of the muscle response. The value for **V2-V1** in the table at the top of the **Analysis** window is the amplitude of the muscle response.

6 The functions in the **channel pull-down menus** of the **Analysis window** can also be used to enter the names and values of the parameters from the recording to the **Journal**. To use these functions:

• Place the cursors at the locations used to measure the muscle response.

• Transfer the names of the mathematical functions used to determine the muscle response to the **Journal** using the **Add Title to Journal** function in the **Muscle Channel pull-down menu**.

• Transfer the values for the change in oxygen concentration to the **Journal** using the **Add Ch. Data to Journal** function in the **muscle channel pull-down menu**.

7 Record the stimulus amplitude used to generate the nerve response along with the other data for the sweep in the **Journal**.

8 Find the amplitudes (**V2-V1**) for the other selected sweeps in the same manner. Record these values and the values of the stimulus amplitudes used to generate these responses in the **Journal**.

9 Graph the amplitude of the muscle response as a function of the stimulus amplitude.

Questions

1 Does the amplitude of the action potential in each fiber in the ulnar nerve increase or do the numbers of nerve fibers in the nerve that respond increase with increased stimulus strength?

2 Does the amplitude of the muscle response increase because the response of each muscle fiber increases or the number of muscle fibers responding increases?

3 Which stimulus amplitudes are subthreshold? Which ones are suprathreshold or submaximal? Which ones are supra-maximal?

Exercise 2: Effect of Stimulus Polarity

Aim: To determine if the polarity of the stimulus pulse delivered to the nerve affects the latency and amplitude of the muscle response.

Procedure

1 Ask the subject to place his or her right hand on the bench with the palm down. Tell the subject to relax.

2 Set the **Amplitude** knob on the front panel of the SI-200 unit to a value that delivers the maximal muscle response as seen from Exercise 1.

3 Click **Record** button on the LabScribe **Main** window to record a single sweep at this stimulus strength.

4 Reverse the polarity of the stimulus pulse delivered to the ulnar nerve by reversing the positions of the stimulating leads on the subject's forearm. Switch the stimulating leads by moving the red (+) stimulating lead to where the black (-) stimulating lead was snapped, and move the black (-) stimu-lating lead to where the red (+) lead was snapped.

5 Click **Record** button on the LabScribe **Main** window to record a single sweep at this stimulus polarity using the same stimulus amplitude.

6 Select **Save** in the **File** menu.

Data Analysis

1 Click the **Analysis** icon in the LabScribe toolbar (Figure HN-3-4 on page HN-3-4) to view all the recorded sweeps.

2 Use the Windows **control-click** function to select the sweeps of interest from the **Sweeps** list on the bottom of the **Analysis** window.

3 Select **Title**, **V2-V1**, and **T2-T1** from the **Add Functions** list if they are not already listed.

4 Go to the **Sweep List** at the top of the **Analysis Window** and select the sweep generated by normal stimulus polarity. Selecting this sweep from this menu will make the values of its measured functions appear in the table at the top of the **Analysis** window.

5 Click the **2-Cursor** icon in the LabScribe toolbar. Place one cursor at the beginning of the stimulus artifact and the second cursor to the peak of the muscle response. The value for **V2-V1** in the table at the top of the **Analysis** window is the amplitude of the muscle response. The value for **T2-T1** is a measure of the latency of the muscle response

6 The functions in the **channel pull-down menus** of the **Analysis window** can also be used to enter the names and values of the parameters from the recording to the **Journal**. To use these functions:

• Place the cursors at the locations used to measure the muscle response.

• Transfer the names of the mathematical functions used to determine the muscle response to the **Journal** using the **Add Title to Journal** function in the **Muscle Channel pull-down menu**.

• Transfer the values for the change in oxygen concentration to the **Journal** using the **Add Ch. Data to Journal** function in the **muscle channel pull-down menu**.

7 Find the amplitude (**V2-V1**) and the latency (**T2-T1**) for the muscle's response to the stimulus of reversed polarity. Record these values in the **Journal**.

Questions

1 How does the amplitude and the latency of the muscle response change when the stimulus polarity is reversed?

2 What causes the difference to occur?

Exercise 3: Conduction Velocity

Aim: To measure the conduction velocity of the ulnar nerve by measuring the time required for the nerve impulse to travel from the site of the nerve stimulation to the site of the muscle response.

Procedure

1 Ask the subject to place his or her right hand on the bench with the palm down. Tell the subject to relax.

2 Set the **Amplitude** knob on the front panel of the SI-200 unit to a value that delivered a maximal muscle response.

3 Click **Record** button on the LabScribe **Main** window to record a single sweep at this stimulus strength.

4 Move the red (+) stimulating lead from Electrode E to Electrode G, and the black (-) stimulating lead from Electrode D to Electrode F.

5 Click **Record** button on the LabScribe **Main** window to record a single sweep with the stimulus delivered at this location on the forearm.

Note: *If you do not get a muscle response with the stimulating electrodes placed farther from the wrist, move the black (-) stimulus lead to Electrode E and the red (+) stimulus lead to Electrode F.*

6 Select **Save** in the **File** menu.

7 Use a measuring tape, measure the actual distance between the two electrodes used as the (-) stimulating electrodes.

Data Analysis

1 Click the **Analysis** icon in the LabScribe toolbar (Figure HN-3-4 on page HN-3-4) to view the recorded sweeps. From the **Sweeps** list, select the sweeps recorded while the stimulating electrodes were in different positions. Superimpose these sweeps on each other by clicking the sweep numbers from this list at the bottom of the window.

2 Select **Title** and **T2-T1** from the **Add Functions** list if they are not already listed.

3 Go to the **Sweep List** at the top of the **Analysis Window** and select the muscle response generated from the proximal position of the stimulating electrodes.

4 Click the **2-Cursor** icon in the LabScribe toolbar. Drag one of the cursors to the peak of the muscle response in this sweep (Figure HN-3-6 on page HN-3-6).

5 Go to the **Sweep List** at the top of the **Analysis Window** and select the muscle response generated from the distal position of the stimulating electrodes.

6 Place the second cursor on the peak of this muscle response. The value for **T2-T1** displayed in the table on the **Analysis** window is the time it took the compound action potential in the ulnar nerve to travel the distance between the two positions of the negative stimulating electrode.

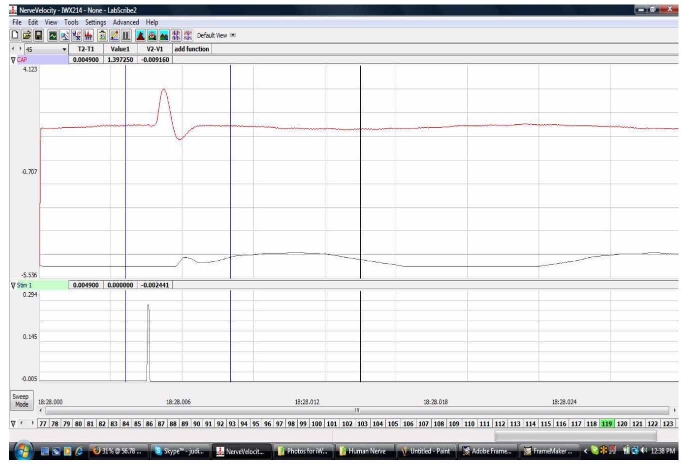

Figure HN-3-6: Cursors mark the time difference between the peaks of the muscle responses caused by stimulating electrodes at two different positions on the ulnar nerve.

7 The functions in the **channel pull-down menus** of the **Analysis window** can also be used to enter the names and values of the parameters from the recording to the **Journal**. To use these functions:

- Place the cursors at the locations used to measure the muscle response.
- Transfer the names of the mathematical functions used to determine the muscle response to the **Journal** using the **Add Title to Journal** function in the **Muscle Channel pull-down menu**.
- Transfer the values for the change in oxygen concentration to the **Journal** using the **Add Ch. Data to Journal** function in the **muscle channel pull-down menu**.

8 Calculate the conduction velocity (in m/sec) by dividing the distance (in mm) between the two positions of the negative stimulating electrode by the time (T2-T1) between the peaks of the muscle responses from those two positions.

- For example:

65mm between positions of (-) electrode / 1.25ms =

52mm/ms = 52m/s