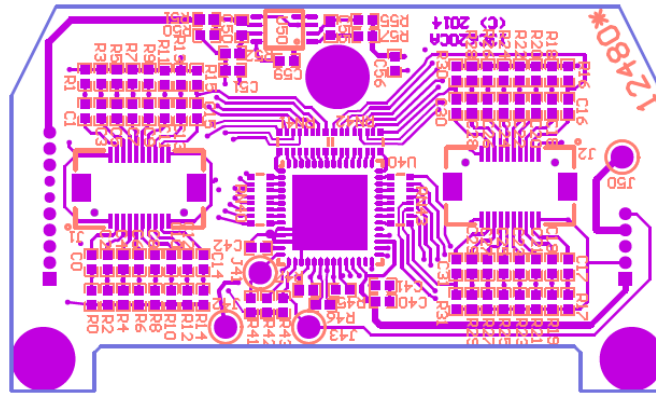


Neurochip3

(Revision D)

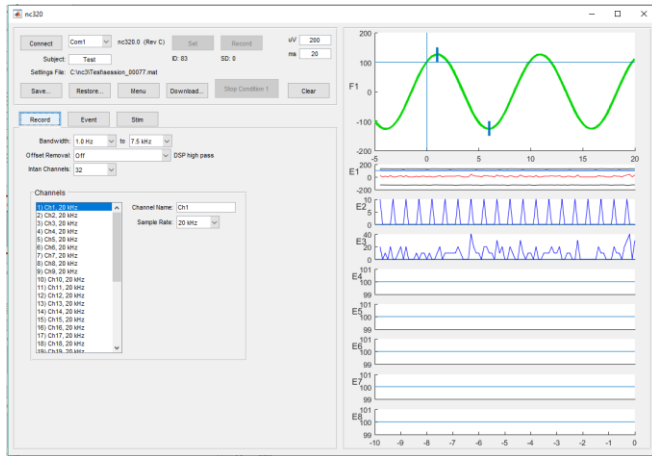


User Interface and Reference Manual Version 3.26

Department of Physiology and Biophysics

University of Washington ©2017

User Interface Installation



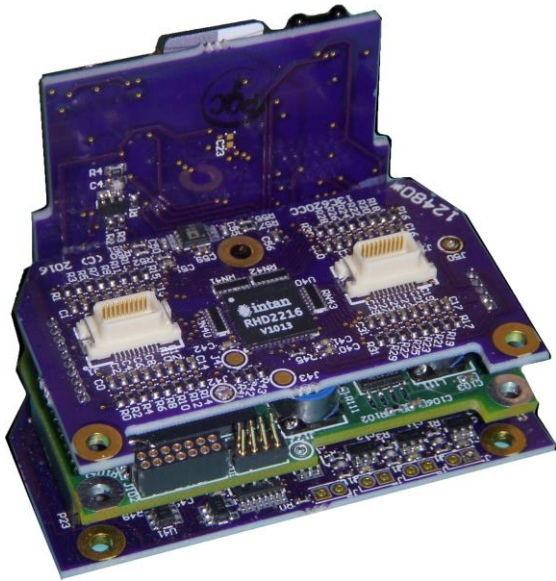
The Neurochip3 user interface program requires the MATLAB programming application from The Mathworks, Inc. running under Microsoft Windows operating system. It has been tested with MATLAB 2007a and MATLAB 2016b. There is a MATLAB mex function that may need to be compiled for your specific version of MATLAB.

The client computer requires a serial port connection for the IR transmitter. A USB to serial adapter can be used if the computer does not have a serial port.

To install the user interface:

- 1) Copy nc326.m, ncsave326.c, ncsave326.mexw32, and ncsave326.mexw64 from the software CD-ROM to a directory in your MATLAB Path. This path is often the /Matlab folder in the /Documents folder.
- 2) Create a folder named C:\nc3. Set permissions on this folder to be writable by all users. This folder will be used to store settings files for recorded data sessions. The name of this folder may be changed by editing the ui.path variable at the beginning of the nc326.m file.
- 3) Create a folder named C:\data. Set permissions on this folder to be writable by all users. This folder will be used as a download folder for recorded data sessions. The name of this folder may be changed by editing the ui.datapath variable at the beginning of the nc326.m file.
- 4) Compile the ncsave326.c mex function with the MATLAB command: `>> mex ncsave326.c`
- 5) Run nc326 from the MATLAB command line.

Neurochip3 Hardware



The Neurochip3 employs an Intan biophysical signal amplifier along with an Atmel SAM4 ARM microcontroller (MCU) and an Altera Cyclone V FPGA to provide the following:

- 32 biophysical recording channels + 3 auxiliary input channels.
- 5, 10, or 20 kHz sample rate individually selectable per channel.
- 6 Stimulation outputs (60V compliance) controlled by up to 8 different experimental conditions.
- 3-Axis Accelerometer.
- Up to 128 GB data storage on UHS-I U3 Class SD Cards.
- 8 Window Discriminators.
- 12 hours normal operation (up to 24 hours with a battery combiner).

Power board (side card)

The Power board contains the IR Port which communicates with the user interface on the client computer, the Micro SD Card which stores collected data, and the red and green status LEDs. It also contains the high voltage power supply circuitry. **Please be careful to avoid touching the back of the power board. The power supply can sustain high voltages for several minutes after power has been disconnected and accidental discharges across the board can damage the Neurochip3.**

The power board has board to board connections with the lower two boards. It is not recommended that normal users take these boards apart. The connectors have considerable friction and pins that can

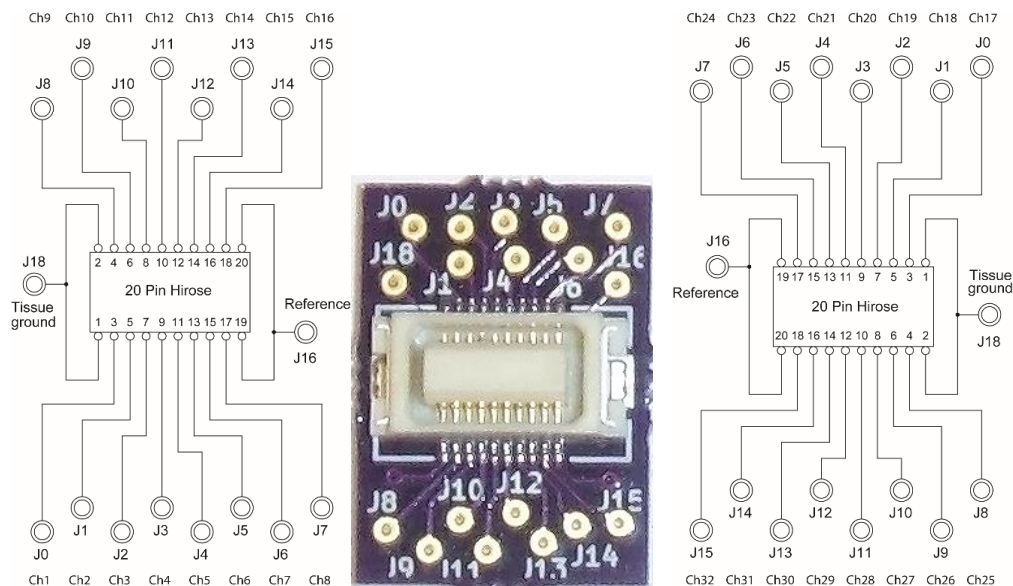
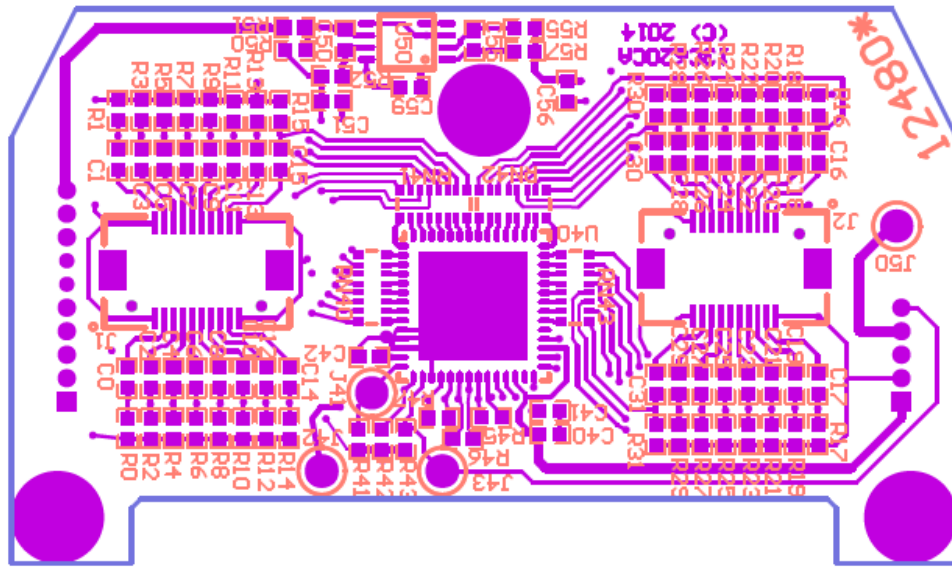
easily be bent or broken if the boards are pulled apart quickly. If the boards must be disconnected, please tease them apart gently with a plastic screwdriver.

The LED indicators have the following functions:

- LED0 Green. Power on indicator. Short off when high voltage is off. Long off when high voltage is on. Located next to top edge of the SD Card connector.
- LED1 Red. Busy/error indicator. Brief blink when setting parameters or when the SD Card is dropping packets. Located below the Power LED.
- LED2 Green. Blinks on any Event. Located next to the Busy LED.
- LED3 Red. Blinks on any stimulus pulse. Located above the Event LED

Input board (top card)

The input board has two Hirose connectors (left and right of the Intan chip) for connecting signals, an indifferent reference input, and a tissue ground. The reference input is used the signal reference for the 32 analog input channels. **Note that a stable tissue ground to a neutral, low impedance, recording point (for example, a skull screw) must be connected for proper recording and stimulation. It should not normally be directly connected to the reference input.**

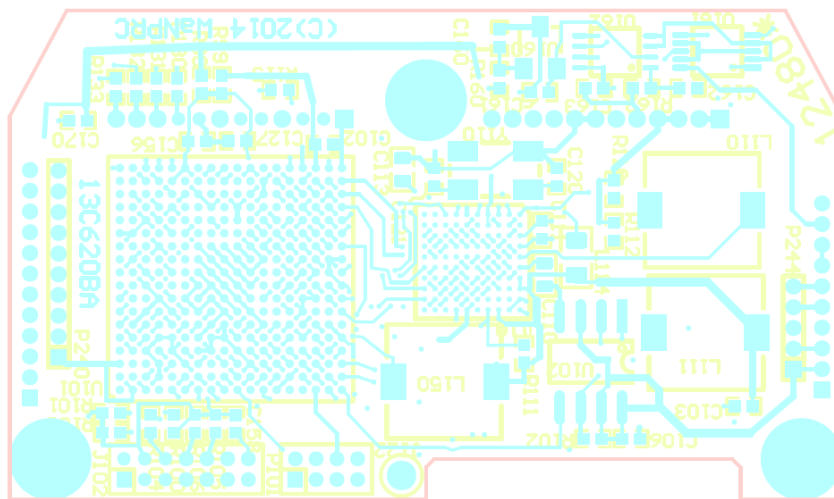


The right input connector is rotated 180 degrees relative to the left input connector. The provided connector boards can be used for both left and right inputs, but the Tissue Ground and Reference should only be connected from one connector board (usually the left board providing Channels 1 through 16).

There are 3 solder points for auxiliary channels Aux1, Aux2, and Aux3. These are labelled J41, J42, and J43. These have an input range of 0 to 2.4 Volts. Note that Aux3 is connected to test circuitry and will normally read as tissue ground at 1.2 Volts. A trace on the Input board will need to be cut in order to use Aux3 for another purpose.

Control board (middle card)

The control board contains the FPGA and MCU. This is where the programming port and peripheral port are located. Normally users will not be using these ports, but the programming port can provide regulated 2.5 and 3.3 volt power for small devices. The peripheral port has direct connections to the FPGA which could possibly be programmed to support additional devices. The hardware schematics show the pin-outs for both these ports (P101 Test and J102 JTAG on schematic 13c620ed.pdf)

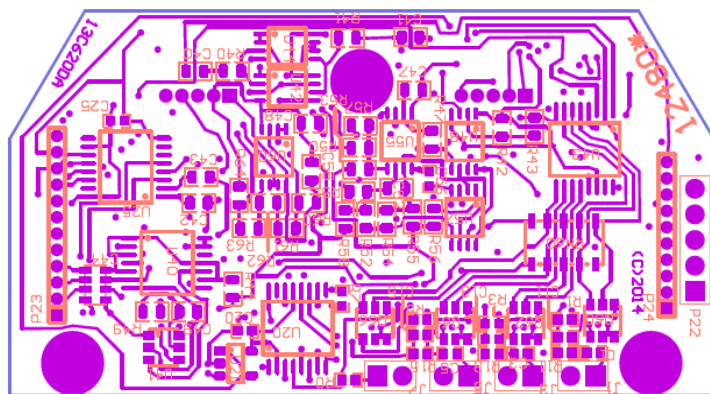


Programming Peripheral

Stimulator board (bottom card)

The battery connector is located on the bottom board (right most connector P22). This connector is orientation independent and keyed so that the battery cannot be plugged in incorrectly as long as all pins on the battery connector are plugged in. Normally one battery is used to power the Control board, while the other powers the Stimulator. However, there is an optional battery combiner board that can be plugged in between this connector and the battery to allow both batteries to power both domains. This generally results in longer run times for experiments with light amounts of stimulation.

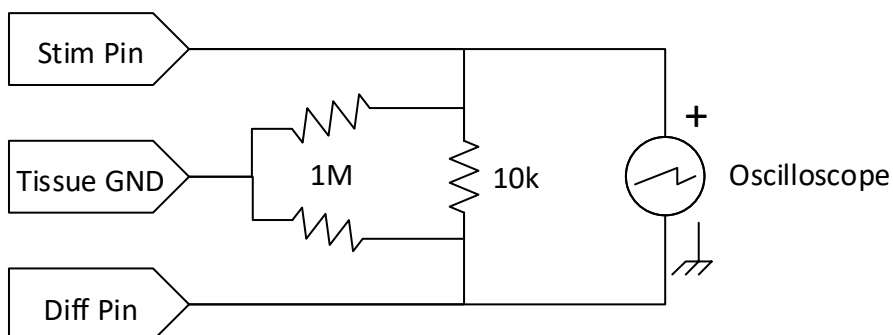
Stimulation is delivered through the six pins C0, C1, B0, B1, A0 and A1. At any one time, one pin may be designated as the stimulus pin and another (optionally) as the differential return. If no differential return is selected, then the return path is to tissue ground. There are two test points for tissue ground next to pin C0. Normally these will not be connected since tissue ground will be connected through one of the Hirose connectors on the Input board.



Battery Connector

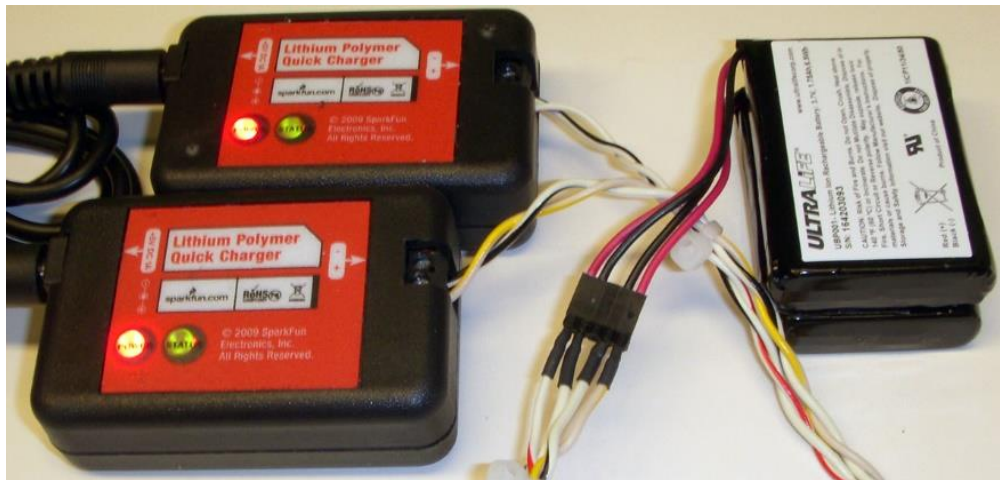
TGND C0/C1 B0/B1 A0/A1

The following circuit can be used to test stimulus outputs with an oscilloscope. With this circuit a 100 μ A stimulation pulse would appear as a +/-1 Volt biphasic square wave on the oscilloscope. If single ended stimulation is used, the differential pin (Diff Pin) is left unconnected.



Battery, Charger, Extender, and Combiner

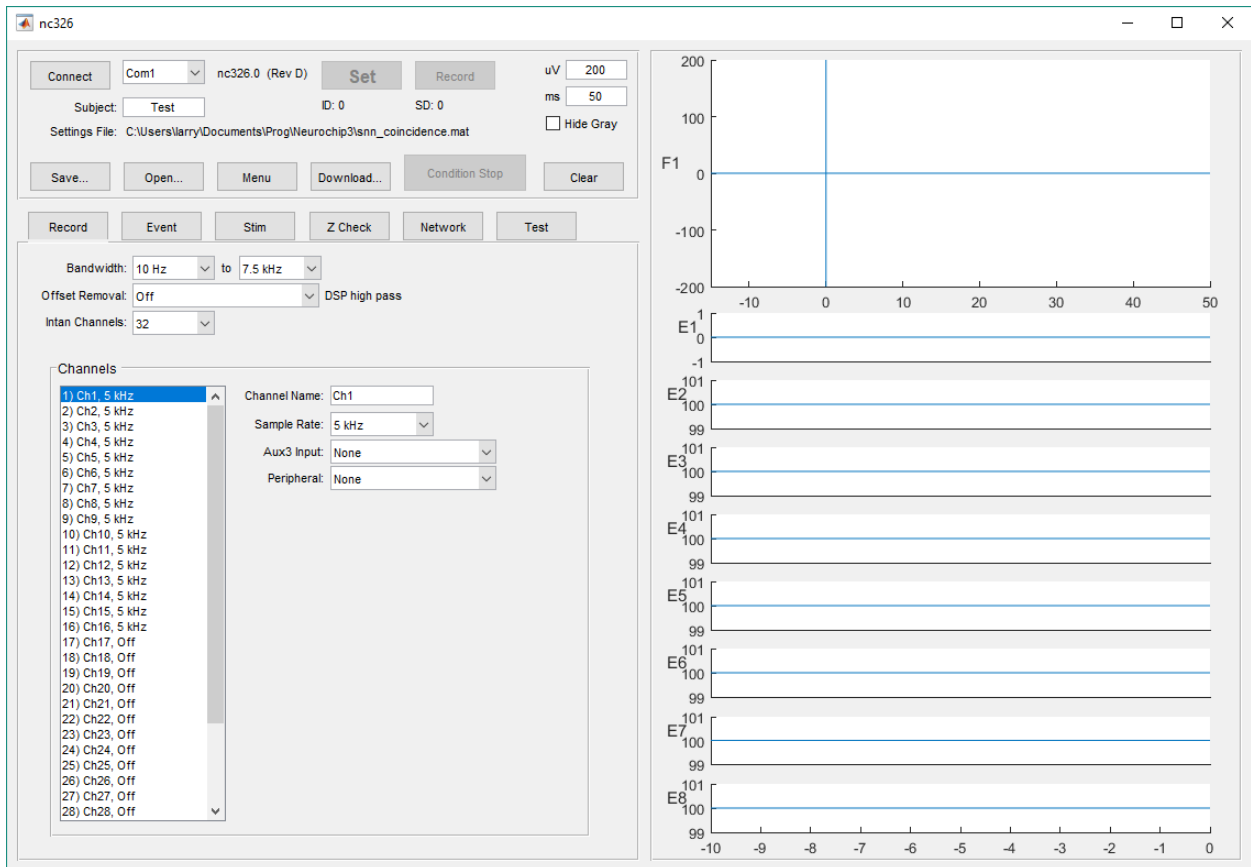
The Neurochip3 is powered by two 3.3V Lithium Ion batteries. Normally one battery powers the stimulator and the other battery powers all other systems. The battery pack and battery extenders are designed so they can be plugged in either orientation (0 degrees or 180 degrees rotated). The battery pack is charged by two quick charger units – one for each battery in the pack. A green light on the charger indicates that charging is active on the corresponding battery. When the light goes dim, that battery is charged. Since one battery may charge before the other, it's recommended to leave the battery pack charging until both green lights go dim.



The battery extender simply adds about 4 inches to the battery leads to allow for easier placement of the battery. The battery combiner is a small blue board (13c620xd) that can be connected between the Neurochip3 and the battery pack to allow the entire Neurochip3 to be run from both batteries. Depending on the use of the stimulator, this can allow the Neurochip3 to run for 24 hours on a full charge of both batteries. Note that recording 32 channels at 20kHz for 24 hours will require a 128GB High Speed U3 Micro SD Card to hold all of the data.

User Interface

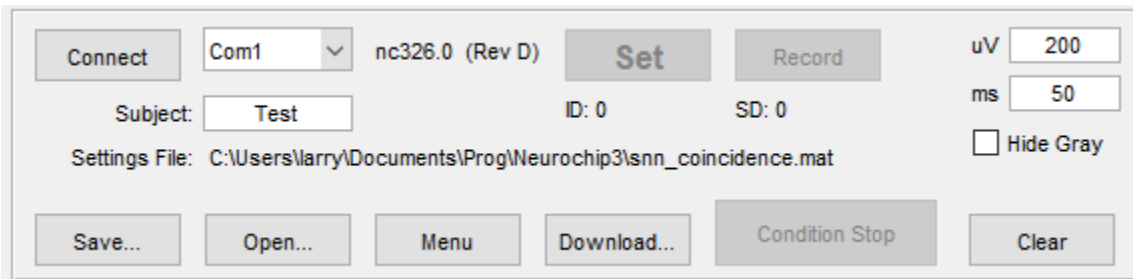
The user interface for the Neurochip3 is a MATLAB script named nc326.m (Neurochip3 interface version 2.2). Once this script has been placed in the MATLAB Path, it is executed by typing its name on the MATLAB command line and pressing the Enter key. This will bring up the user interface window after a few seconds as shown below.



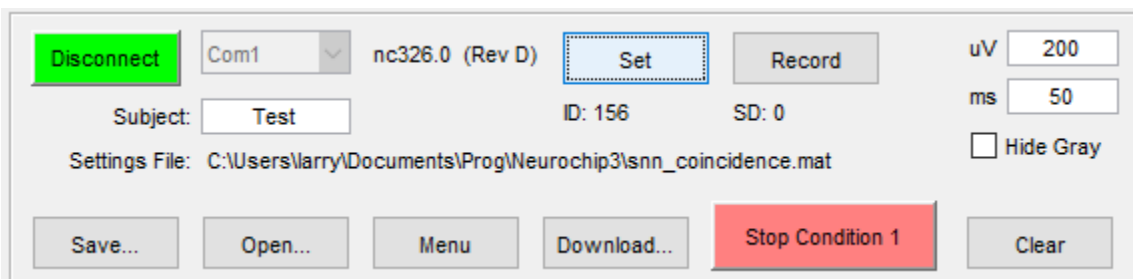
When the interface starts, it loads the last saved settings file. Settings files are saved by the user with the Save... button, and are created automatically when the Record button is pressed.

The Main Control Panel

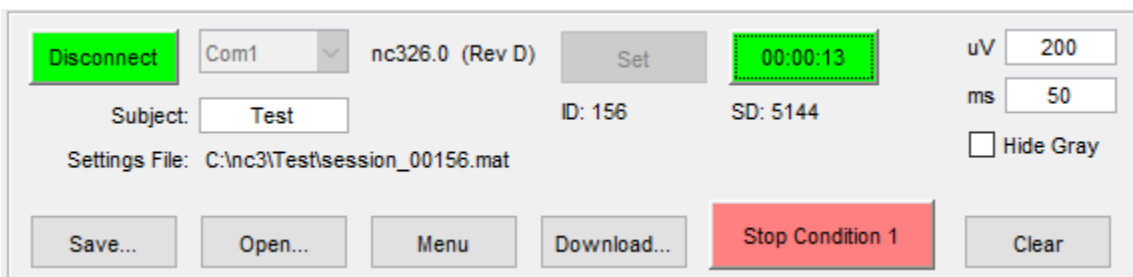
The main control panel contains buttons for connecting to the Neurochip3 through the IR adapter, sending parameters to the Neurochip3, starting data acquisition, downloading data from an SD Card, and opening and saving Neurochip3 settings files.

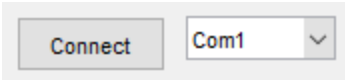


Some of the buttons will change color depending on the state of the Neurochip3. For example, after the Connect button has been pressed, the Connect button will turn green when a successful connection is established and the firmware version of the Neurochip3 is displayed. The Set button will copy current parameters to the Neurochip3 and restart data collection. A Session ID will be shown below the Set button to indicate the ID number associated with the current data. This ID will be recorded to the SD Card if the Record button is pressed and is used to match data on an SD Card with a settings file. While connected, the Stop Condition button can be used to halt all stimulation and enter a condition where no stimulus can be delivered until the Set or Record button is pressed again.

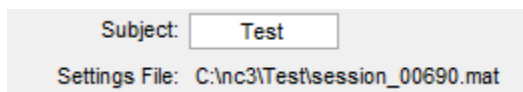


While recording, the recording time will be shown on the Record button and the current SD Card sector will be shown below it. Press this button again to stop recording.





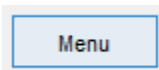
The Connect button will start or stop communications through the IR adapter connected to the selected Com port. If a USB adapter is used, the corresponding Com port can be found in the Windows Device Manager. The IR adapter has about a 0.5 meter range in a 30 degree cone above the IR port located on the top right edge of the power board. Once a connection has been made, the Connect button will turn green and be relabeled as "Disconnect" and data will be continuously exchanged between the user interface and the Neurochip3. Pressing the Disconnect button will cease this data exchange. Be aware that IR signals can bounce and may be picked up by more than one active Neurochip3 which will confuse both devices and experimenters alike.



The Subject name is used to separate settings and data downloads into similarly named directories. The current settings file is shown just below and indicates the last file from which settings were loaded or saved. Settings files are automatically saved as Session files (named with the current Session ID) so that data downloads from SD Cards can be paired with their correct settings. If an SD Card is downloaded to a different computer, the Session file will need to be copied to the expected folder.

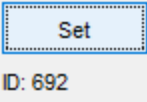


The Save... and Open... buttons will save and restore settings files to and from user selected files.

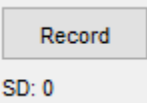


The Menu button will toggle on and off the MATLAB figure menu. This can be useful for printing the settings window or zooming in on a graph (when not connected).

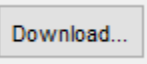




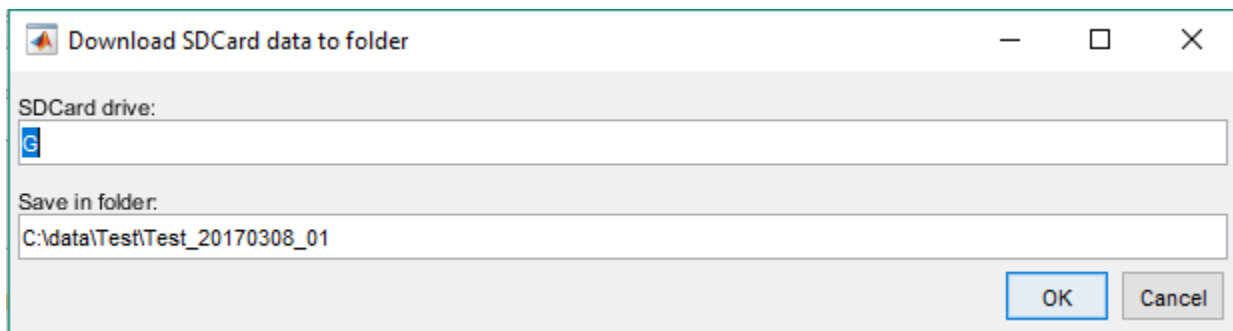
The Set button is used to copy current user interface parameters to the Neurochip3. It only works when the Connect button is highlighted in green. When parameter changes are made, the word “Set” will be shown in Bold to indicate there are differences between the interface parameters and those currently running on the Neurochip3. The Session ID number is incremented each time the Set button is pressed. This ID number is used to pair recorded data with correct settings file.



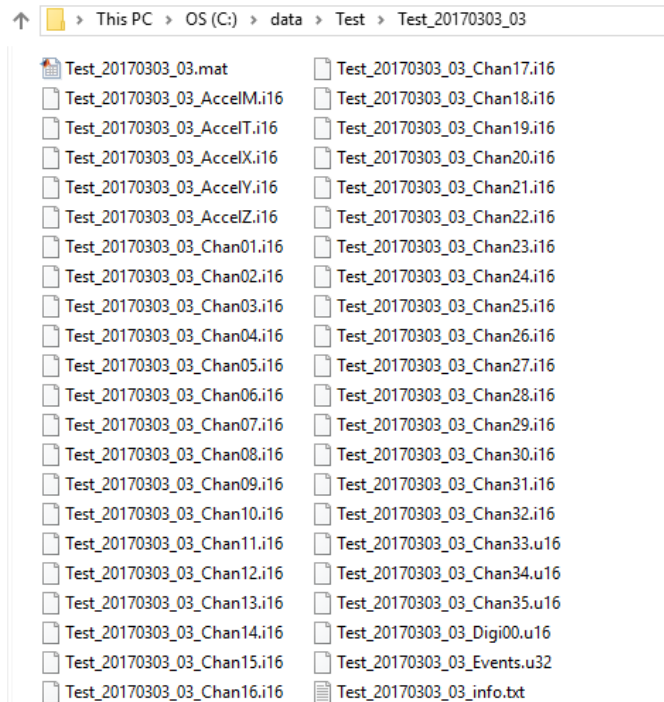
The Record button is used to start recording with the current session ID. If successful, recording will start, the Record button will be highlighted in green (counting out recorded time), and the SD: sector number will start incrementing. Usually when recording fails to start, the SD Card is missing or not seated correctly.



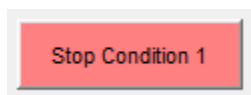
The Download button will start the process of copying previously recorded data off of an SD Card to the client computer’s hard drive. The user must insert the SD Card into a USB reader device and plug the reader into the client computer. Windows will complain about the card not being formatted, but it is important to disregard those messages and not format these SD Cards. These SD Cards are used in raw data mode and do not contain a file system. Windows will, however, assign a Drive Letter to the card which you will need to supply in the following dialog box that will be displayed by the Download button.



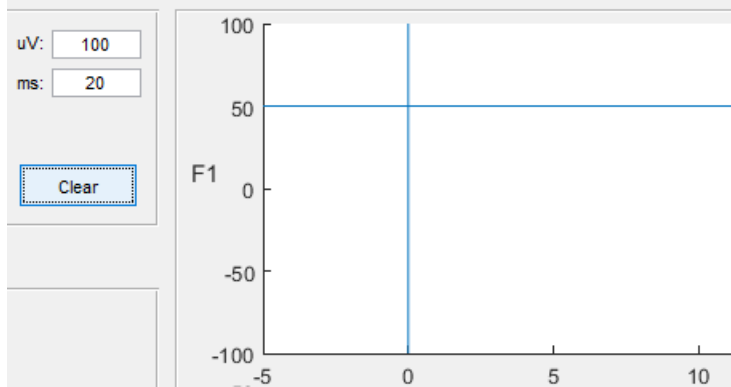
The default destination folder contains the Subject name and current date, but may be changed to any other valid folder. Downloaded data will be stored with channels separated each into its own file. Note that a full SD Card can take an hour to download, so be prepared with enough time or by swapping in an unused SD Card. The Neurochip3 CD-ROM includes demonstration functions showing how to access data in these files.



The above is an example of a data download. There is a text file describing the folder contents and a copy of the settings file saved with a .mat extension. Channel files are saved with a .i16 extension to indicate they contain 16-bit signed integers which can be converted into μV units by multiplying by a factor of 0.195 (from the Intan spec sheet). Aux channels are saved as unsigned 16-bit integers which can be converted into Volts by multiplying by a factor of $(2.4 / 65536)$. The accelerometer channels are all saved at 100 samples per second and are already scaled in milli-gravities ($1\text{g} / 1000$). There is also an accelerometer temperature channel scaled in Celsius, however this is not likely to be an accurate measure of ambient temperature and is mostly for diagnostic purposes. The Events.u32 file contains timestamps of events, stimulations, condition switches, and missing sections of data. It can be read with the nc3events.m Matlab script included on the software CD-ROM.



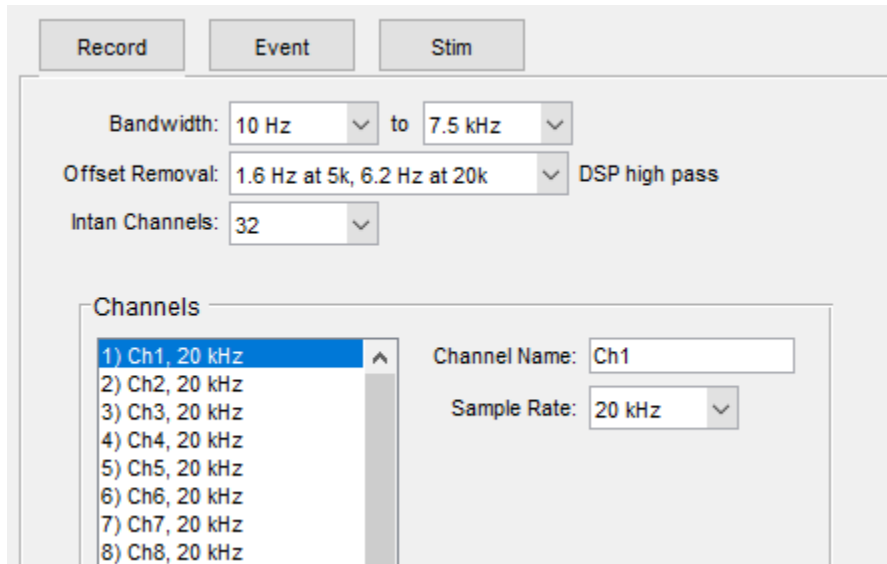
The Stop Condition button will stop all stimulation until the Set or Record button is pressed again. This button is only available when the Connect button is active. It should be used any time stimulation is active and the user is about to change physical connectors. It will also inform the user of the current stimulation condition as long as the connection between the interface and the Neurochip3 is active.



The Clear button and the uV: and ms: text boxes are used to clear and set the scales of the sweep display described later in this manual.

The Record Panel

Pressing the Record button will display the Record panel below.



In this panel, the user selects settings for the Intan chip included sample rates for each channel and the filter bandwidth that affects all channels. An optional offset removal can be selected that remove signal offsets by applying a digital high pass filter to data samples leaving the Intan chip. These settings affect the data stored on the SD Card.

Bandwidth: 10 Hz to 7.5 kHz

The Bandwidth low cut is selectable from 0.1 Hz to 500 Hz. Very low values for the low cut may lengthen stimulus artifacts. The high cut is selectable from 100 Hz to 10 kHz, and should be set no more than half of the lowest analog sampling rate used.

Offset Removal: 1.6 Hz at 5k, 6.2 Hz at 20k DSP high pass

The Offset Removal will activate a digital high pass filter on the Intan chip. It can be used to reinforce the Bandwidth low cut, but be aware that the frequency cut-off will vary depending on the sampling rate of the each channel. This is why the cut-off at 5k Hz and 20k Hz sample rates are both listed. The cut-off for 10k Hz will be half of the 20k value. It's a good idea to check signals with the Offset Removal set to Off to make certain that signals are within the +/-5 mV input range.

Intan Channels: 32

The Intan Channels drop down menu switches between the 16 channel and 32 channel Intan chips. It's allowed to run the 32 channel chip in 16 channel mode, but only the left bank of inputs will be available.

Channels

1) Ch1, 20 kHz	Channel Name: LFP2
2) Ch2, 20 kHz	Sample Rate: 10 kHz
3) EMG1, 5 kHz	Aux3 Input: Tissue Ground
4) EMG2, 5 kHz	
5) LFP1, 10 kHz	
6) LFP2, 10 kHz	
7) Ch7, Off	
8) Ch8, Off	

The Channels panel allows the user to select individual sample rates for each channel and to assign nicknames that will be used when selecting channels for the window discriminators in the Events panel.

Aux3 Input: B1 Voltage Check

The Intan Aux3 Input is connected to some internal test points and can be used to monitor Tissue Ground or the voltage control lines for each of the stimulus output pins (A1,A0, B1,B0, C1,C0 correspond to VC1,VC2, VC3, VC4, VC5,VC6 on schematic 13c620ed.pdf). This can be used test for expected voltage waveforms for the stimulus outputs -- although these are singled ended test points and won't have the exact waveform of the resulting current stimulus. These test points should be symmetric around Tissue Ground. If Aux3 is monitored by one of the Event channels, an Event filter of 10Hz-10000Hz can be used to remove the Tissue Ground offset. If Aux3 is needed for another purpose, a trace on the top board connecting J43 to this test circuitry may be cut.

Peripheral:

The Peripheral input pulldown menu is used to select between specialized uses of the FPGA input/output port. Currently this is used for testing purposes only and should be set to “None” for normal use. The two settings available, “Serial Event Transmitter” and “SPI Data Transmitter”, can output events and data samples that might be used in the future to drive additional hardware.

The Event Panel

Pressing the Event button will display the Event and Window Discriminator panel below.

Record **Event** Stim

Event 1 On

Source: -

Transform:

Bandwidth: to Hz (0,0 = off)

Threshold: uV

Window1 Delay: ms Window2 Delay: ms

Max1: uV Max2: uV

Min1: uV Min2: uV

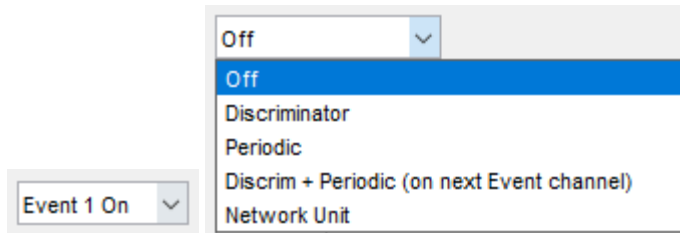
Refractory Period: ms after event inside of ms

Periodic Events

Minimum Interval: ms Maximum Interval: ms (0 = off)

Event Ratio 1: Poisson Rate: Hz (0 for Uniform)

In this panel, the user can define up to 8 event generators which can be based on dual time-amplitude window discriminators and periodic timers.

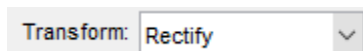


The Event drop down menu is used to select the current Event channel which can show sweeps of data in the sweep display on threshold detections. The drop down menu immediately to the right will select if the Event is generated by a window discriminator, a periodic timer, or a combination of both (where the Periodic events will appear as if they were generated by the next higher Event channel). The last option in the menu is to route the spiking output of a neural network unit (which must be selected with a check box in the Network tab).

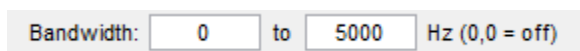
Window discriminators will trigger events when a chosen signal rises through a threshold and then passes through two level detectors (windows) at specific delays from the threshold crossing. Sweeps of data are shown in the sweep display (upper right plot area) about once per second. Each sweep is triggered off threshold detection and will be plotted in green if MATLAB predicts that the sweep will travel through both windows.



The Source drop down menus select which input channels (including accelerometer channels) will be used as the discriminator signal. This allows you to invert or subtract two channels. The user may select a Source simply to view sweeps of data in the sweep display. In that case, the Threshold would need to be adjusted to be within signal range, or a Periodic timer could be used to generate a periodic sweep of Source data.



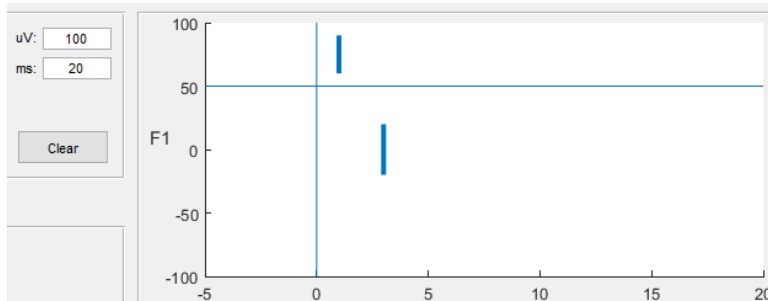
The only transform currently available is to rectify the Source data. Other data transforms may be added here in the future. Rectification occurs before the Butterworth filter is applied. The Offset Removal feature in the Record panel can be used ensure the rectification occurs around the signal mean.



A first order bandpass or second order low pass Butterworth filter may be applied to the Source signal here. If the low cut is 0, the low pass filter is used. If both the low and high cut values are zero, then no filter is used.

Threshold: uV
 Window1 Delay: ms Window2 Delay: ms
 Max1: uV Max2: uV
 Min1: uV Min2: uV

The Threshold and dual time-amplitude windows allow detection of unit spikes and other waveforms. When the Source signal rises through Threshold and then goes through both windows at their respective delays from the threshold crossing, an event is generated that can be used to trigger or gate a stimulus. The Threshold and windows for the current Event will be drawn in the Sweep display.



Refractory Period: ms after event inside of ms

A refractory period may be imposed on event acceptances to limit the rate of events or to bypass artifacts caused by stimulation. Typically, “after 1 event” is used to for a refractory period after each accepted event. However, “after” values greater than 1 can be used to impose a time out after a certain number of events occur inside the given time limit. This can be used to allow a time for periodic events to occur interspersed with discriminated events when the option to use both is selected.

Periodic Events
 Minimum Interval: ms Maximum Interval: ms (0 = off)
 Event Ratio 1: Poisson Rate: Hz (0 for Uniform)

The parameters for periodic events define the event intervals when “Periodic” events are selected from the event type drop down menu. The minimum and maximum intervals are used to generate uniform distributions between two values. If an exponential distribution is desired, a non-zero value is entered into the Poisson Rate box. In this case, the minimum and maximum intervals are still observed, so the actual event rate may not be exactly equal to the entered value. A more Gaussian distribution can be achieved by adding intervals together with the Event Ratio value. For example, entering a value of 2 into this box would cause every other interval to generate an event, entering 3 would cause every third interval to generate an event.

The Stimulation Panel

Pressing the Stim button will display the Stimulation panel below.

Delay ms	Level uA	Width ms	Pulse count	ISI ms	Limit count	Limit sec	Time-out	Stim Pin	Diff Pin
0	10	0.2	2	2	200	1	5	A1	A0
10	200	0.2	1	2	200	1	5	B1	B0

This panel lets the user define up to 8 different experimental conditions. Conditions operate for a given duration and then proceed to the next specified condition. Each condition may have its own stimulation requirements. For stimulation to occur on an output pin, the following must be true:

- 1) Stimulation Power must be on.
- 2) The desired stimulation Channel must be active (in the current Condition) with a Pulse Count \geq 1 and a Stim Pin selected.
- 3) A Stimulation Requirement must trigger the stimulation Channel in the current Condition.

Stimulator Power: Off

Starting Condition: Off

10 Volt Compliance

60 Volt Compliance

The Stimulation Power drop down selects between three power modes: Off, 10 Volt, and 60 Volt compliance. If the stimulator won't be used, set this drop down to "Off", which will save power and prevent the high voltage capacitors from charging. For low amounts of stimulation, the 10 Volt setting may be used. This setting attempts to model the Neurochip2 low-voltage stimulator. The 60 Volt Compliance setting is the normal operating setting when stimulation is desired.

Note that even if the Stimulator Power is off, the Neurochip3 will still run through normal stimulation sequences and record stimulation pulse times. This can be used to run a control for stimulation experiment, or to test a stimulation paradigm without delivering any current.

Intan Fast Settle: 600 uS on each pulse

The Intan Fast Settle drop down is used to control the Intan chip's ability to settle amplifier coefficients to zero for a brief interval on each stimulation pulse. The hope here is that this will prevent stimulation artifacts from being integrated into the recorded signals. Care needs to be taken when using this feature since the fast settle can create an artifact of its own. This is particularly the case when a signal has a significant offset from zero and the amplifier needs to integrate the signal back up to that level after each fast settle application. That integration time is affected by the bandwidth low cut frequency with lower frequency cut offs requiring longer integration times. The recommended value is 200 uS beyond the end of the second stimulus phase. When using a stimulus phase width of 0.2 ms, the recommended value would be $0.2 \text{ ms} + 0.2 \text{ ms} + 200 \text{ uS} = 600 \text{ uS}$.

Event Filter Suppression: 0 ms on each pulse

The Event Filter Suppression time only effects signals used by the Event Discriminators. It will hold the current sample for a number of milliseconds on each stimulation pulse to prevent stimulation artifacts from being integrated into the discriminator signal. This value should be set as low as possible while still removing the artifact.

Starting Condition: Condition 1

There are eight possible experimental conditions available for testing out different stimulation paradigms. Select the Starting Condition to test out or start with the desired condition. This condition is started each time either the Set or Record button is pressed.

Condition 2 Settings

Duration: 300 sec Proceed to: Condition 1 99 repetitions

Channels: 2 2nd Phase

	Delay ms	Level uA	Width ms	Pulse count	ISI ms	Limit count	Limit sec	Time- out	Stim Pin	Diff Pin
Stim 1:	0	100	0.2	1	2	200	1	5	A1	A0
Stim 2:	0	-200	0.2	2	2	200	1	5	B1	B0

Each Condition is defined by its number (1 through 8), and may have separate settings for duration, sequencing, and stimulation outputs.

The Duration time is given in seconds with a special value of 0 denoting an unlimited duration. When the duration expires, control will proceed to the listed condition or the next condition if the given number of repetitions has already been done.

Channels: 2

The number of stimulation channels can be set from 0 to 6. This allows you to set up to 6 different stimulus waveforms per condition. Set the number of channels to 0 to disable all stimulus pulses for the selected condition.

Delay
ms

Stim 1: 0

The stimulus delay is the number of milliseconds to wait after the triggering event to deliver the first phase of the stimulation pulse. Note that only one stimulation pulse may be active at any given time. If pulses would overlap, one of the pulses will be further delayed to prevent that from happening. Also note that only 250 pending triggering events may be stored for each stimulation channel. If long delays are used, make sure that the event rate will not overflow 250 events within the delay period, otherwise events will be lost.

Level
uA

100

The stimulation level is the current output for the first stimulation phase on the Stimulus Pin. A positive value produces a positive first phase voltage on the Stimulus Pin. A negative value will invert the waveform and produce a negative Voltage on the Stim Pin for the first phase. Note that these values are relative to Tissue Ground, and that a good tissue ground connection must be made in order for the stimulation levels to be accurate.

Width
ms

0.2

The phase width is the width of both the positive and negative phases of the stimulus pulse. The total length of each pulse will be twice the give value.

Pulse
count

1

The pulse count is the number of pulses triggered by an event. This allows the user to setup a pulse train in response to a single event. Care must be taken to adjust the inter-stimulus interval so as not to deliver excessive stimulation.

ISI
ms

2

The Inter-Stimulus Interval is the minimum allowed interval between stimulus pulses. In a pulse train, it will be the inter-pulse interval, otherwise it acts as a refractory period.

Limit
count

200

Limit
sec

1

Time-
out

5

The Limit Count, Limit Sec, and Time-out values provide a way of suspending stimulation should the number of pulses exceed a given limit. In this example, when more than 200 pulses occur within a 1 second window, stimulation on the channel will time-out for 5 seconds. Note that the 1 second window is not a sliding window, but rather back to back 1 second windows. This means that it is possible to exceed the given limit if there are high amounts of stimulation spread over two adjacent windows. The user needs to account for this possibility.

Stim
Pin

A1

Diff
Pin

A0

The Stim Pin drop down menu selects the stimulus output pin to produce the output waveform. Any of the six output pins may be selected. The Diff-Pin menu selects the return path for differential stimulation. If single ended stimulation is desired, the Diff-Pin may be set to Off, then the return will be to tissue ground.

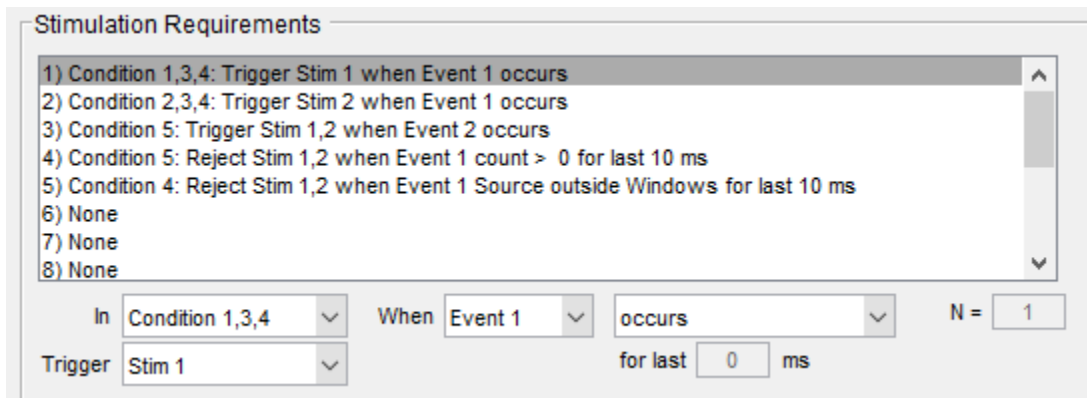
2nd Phase

2nd uA Width

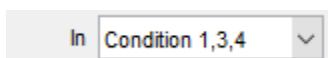
10

0.2

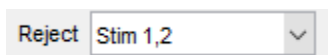
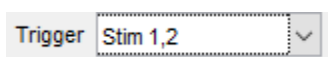
An optional amplitude and width for the second stimulation phase are available by checking the 2nd Phase checkbox. This allows you to create an asymmetrical biphasic stimulation shape. The sign of the amplitude is ignored here and will always be opposite of the first phase amplitude when the stimulation is delivered. It is recommended that both phases be balanced in terms of area (absolute amplitude * width).



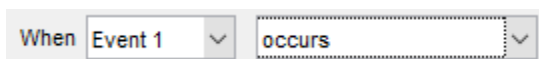
Stimulation Requirements specify the circumstances under which stimulation pulses will be delivered. The requirement list is processed in order with triggers based on event occurrences normally coming before lines which will reject the accepted triggers. Multiple stimulation channels can be triggered in multiple conditions by a single event. Those triggers may be rejected based on recent activity on an event channel. For example you can reject a trigger if there has been too much or too little activity on an event channel, or if the source signal for an event channel is within its windows or is outside of its windows for a given duration.



The In Condition dropdown menu is used to toggle under which conditions a Requirement is active. A Requirement may be active in any or even all conditions.



The Acceptance dropdown menu is used to select which stimulation channels are accepted (on event occurrences) or rejected based on recent event activity. Any combination of stimulus channels may be selected with this menu.



This combination of Event and Method is used to trigger Stim channels. Selecting “occurs” from the Method dropdown will change the Acceptance dropdown title to “Trigger”.

When ms

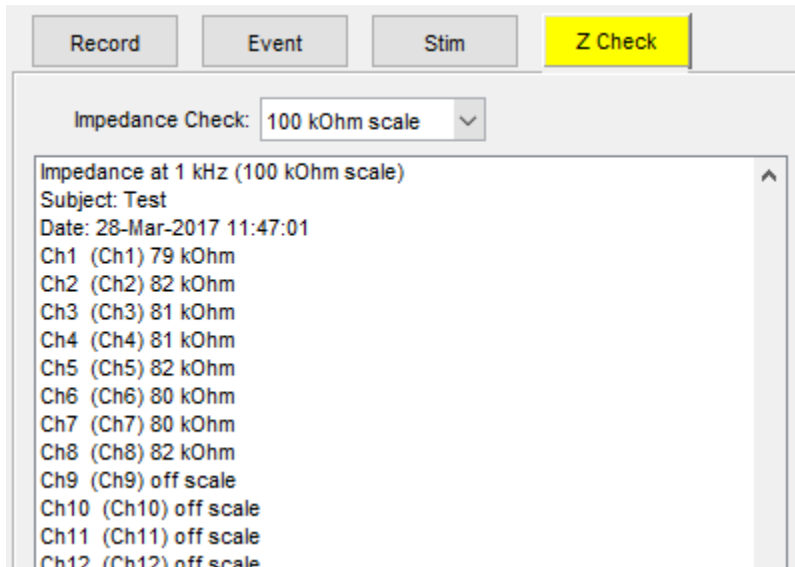
This combination is used to reject previously accepted Stim channels when the Source analog for an Event channel is inside/outside of its given windows. Note that a Source signal goes inside of its Windows when it is within the boundaries of both Window1 and Window2. The Source goes outside of its Windows when it is outside the boundaries of both Window1 and Window2. This provides some hysteresis when the Source is inside one window but outside the other window. If no hysteresis is desired, then the Min and Max range for Window1 and Window2 should be set equivalent.

When ms

This combination is used to reject previously accepted Stim channels based on the number of events which have occurred in a recent time interval. This can be used gate stimulation off when there is too much or too little activity on an Event channel.

The Impedance Test Panel

Pressing the Z Check button will display the impedance testing panel below.



To turn on impedance testing, make sure the Connect button indicates a stable connection to the Neurochip3, then select the proper Impedance Check scale, and click the Set button. The Impedance Check scale determines the amplitude of the current sine wave used in the test: 38 nA for the 100 kOhm scale, and 3.8 nA for the 1 MOhm scale. The Impedance Check scale must be set to Off for normal Neurochip3 operation. The Z Check button will be highlighted in yellow as a warning that normal Neurochip3 operation will be overridden when the impedance test would be activated by the Set button.

During impedance testing, the Neurochip3 will scan through all 32 Intan input pins testing each pin in sequence. Make certain that the number of Intan channels in the Record panel matches the Intan chip on the Neurochip3: 16 for the Differential Intan chip and 32 for the Single Ended Intan chip. The Differential Intan chip will test the positive and negative input terminals separately.

The impedance values returned include all of the in-series impedance of the Neurochip3 and Intan chip. This includes a 22 nF capacitor and 1.5 k resistor which will give about 8 kOhm impedance at 1 kHz. The results will better reflect the impedance of the actual electrodes when electrode impedance > 15 kOhm.

The Network Panel

The Network Panel contains settings for the Spiking Neural Network (SNN). This runs an integrate and fire neural network simulator that can be used to process and generate events defined in the Event Panel.

The screenshot shows the Network Panel interface with the following settings:

Spiking Neural Network:

- Number of Units: (0 = off)
- Threshold: uV
- Bias Amplitude: uV
- Bias Frequency: Spikes/sec
- PSP Slow Decay:
- PSP Fast Decay:
- Conduction Delay: ms (0.1 to 3.5)

Output:

- Unit1 -> Event1
- Unit2 -> Event2
- Unit3 -> Event3
- Unit4 -> Event4
- Unit5 -> Event5
- Unit6 -> Event6
- Unit7 -> Event7
- Unit8 -> Event8

Weight List: FromUnit ToUnit Weight

-7	1	3500
-8	1	3500

The SNN may contain up to 256 units. The first 8 of these units may be output units which send their spiking activity to the Event generators defined in the Event panel. Input spikes to the SNN units come from either the 8 Event generators (which are defined as units -1 down to -8) or from the randomly generated bias spikes which every unit receives as an independent spike stream. The network runs at 10000 updates per second.

When the "Set" button is pressed, the SNN parameters and weights will be downloaded to the Neurochip3 along with all the other settings. The SNN weight list can include up to 2000 weights which may take several seconds to download. If the network was downloaded successfully, it will start running and the "Network" tab will light up green. If the tab lights up yellow, then the weights did not download correctly and the "Set" button should be pressed again.

Integrate and Fire Network Model

The network model is comprised of n integrate and fire units and a list of up to 2000 directed connections from Events or between unit pairs. Each unit maintains a potential $V_i(t)$ which represents an integration of recent activity (at time t) from units with connections to unit i . Unit potentials are calculated at discrete time steps where t is a non-negative integer. When incoming spiking activity causes a unit's potential to exceed a threshold θ , the unit is said to have "fired" and the unit spike function $U_i(t)$ is set to 1 for that time step. Each time a unit fires, its potential will be reset to zero and an output spike will be initiated from that source unit to all of its target units.

The integrated spiking activity of the modeled units is meant to represent the summed post synaptic potentials (PSPs) of an actual neuron. In order to achieve a PSP shaped effect on each unit potential for every arriving spike, $V_i(t)$ is defined as the difference between a slow $V_{s_i}(t)$ and a fast $V_{f_i}(t)$ exponential decay function modeled as simple leaky integrators with multiplication constants $kslow$ and $kfast$. If $A_i(t)$ is the sum of all incoming activity to unit i , then the unit potential $V_i(t)$ is modeled as follows.

$$V_i(t) = V_{s_i}(t) - V_{f_i}(t)$$

$$U_i(t) = 1, \text{ if } V_i(t) > \theta; 0 \text{ otherwise}$$

$$V_{s_i}(t + 1) = kslow \times V_{s_i}(t) + A_i(t), \text{ if } U_i(t) = 0; 0 \text{ otherwise}$$

$$V_{f_i}(t + 1) = kfast \times V_{f_i}(t) + A_i(t), \text{ if } U_i(t) = 0; 0 \text{ otherwise}$$

$$1 > kslow > kfast$$

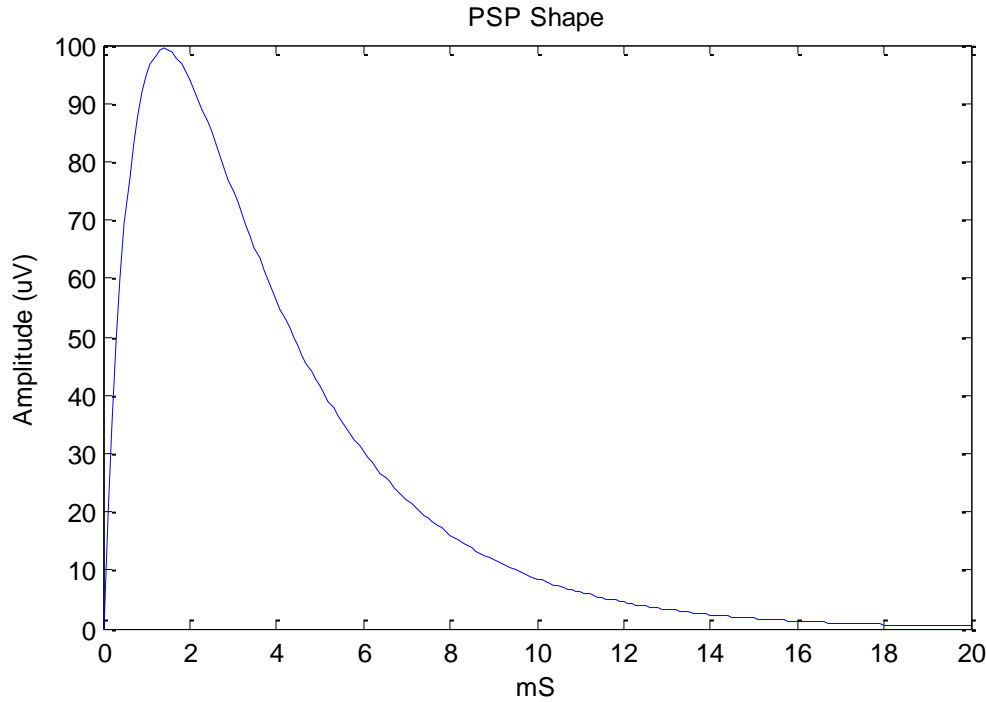


Figure 1. PSP Shape. The *kfast* and *kslow* constants create a PSP shaped deflection in a unit's potential for every incoming spike. Typical values are *kfast* = 0.9688, *kslow* = 0.875 which yields a PSP shape peaking at 1.5ms and running nearly its full course within 20ms.

Each connection is defined as a weight W_{ij} linking source unit j to target unit i . This weight is the maximum height of the PSP Shape and so must be multiplied by a scaling value α (which is calculated internally from the *kfast* and *kslow* parameters) before summation into a unit's potential. Axonal and dendritic conduction times are modeled as a global delay parameter d for all connections. Bias input to each unit is $E_i(t)$, the sum of all bias spikes arriving to unit i at time t . With this information, $A_i(t)$ is defined as follows.

$$A_i(t) = E_i(t) + \sum_{j=-8}^n (U_j(t-d) \cdot \alpha \cdot W_{ij})$$

$$E_i(t) = \alpha \cdot BiasAmplitude, \text{ if } RandomChance_i(t) < BiasChance, 0 \text{ otherwise}$$

Since the network runs at 10000 updates per second,

$$BiasChance = BiasFrequency / 10000$$

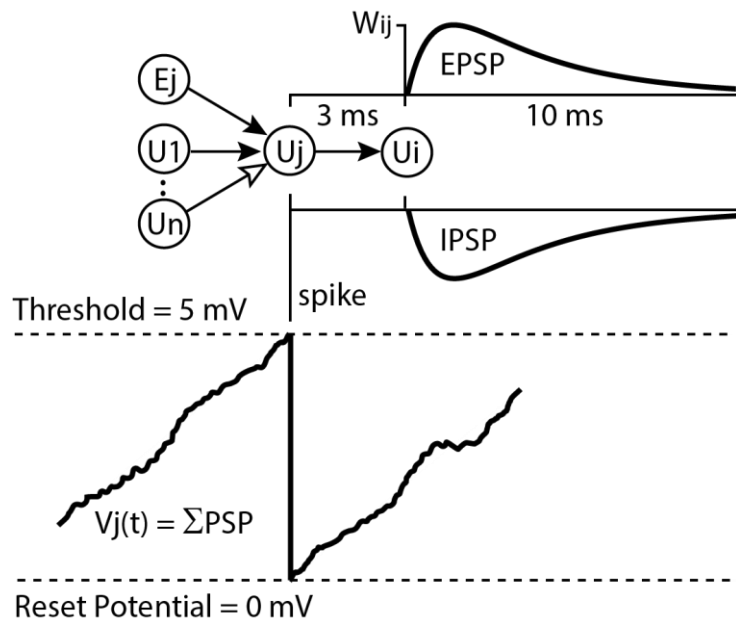
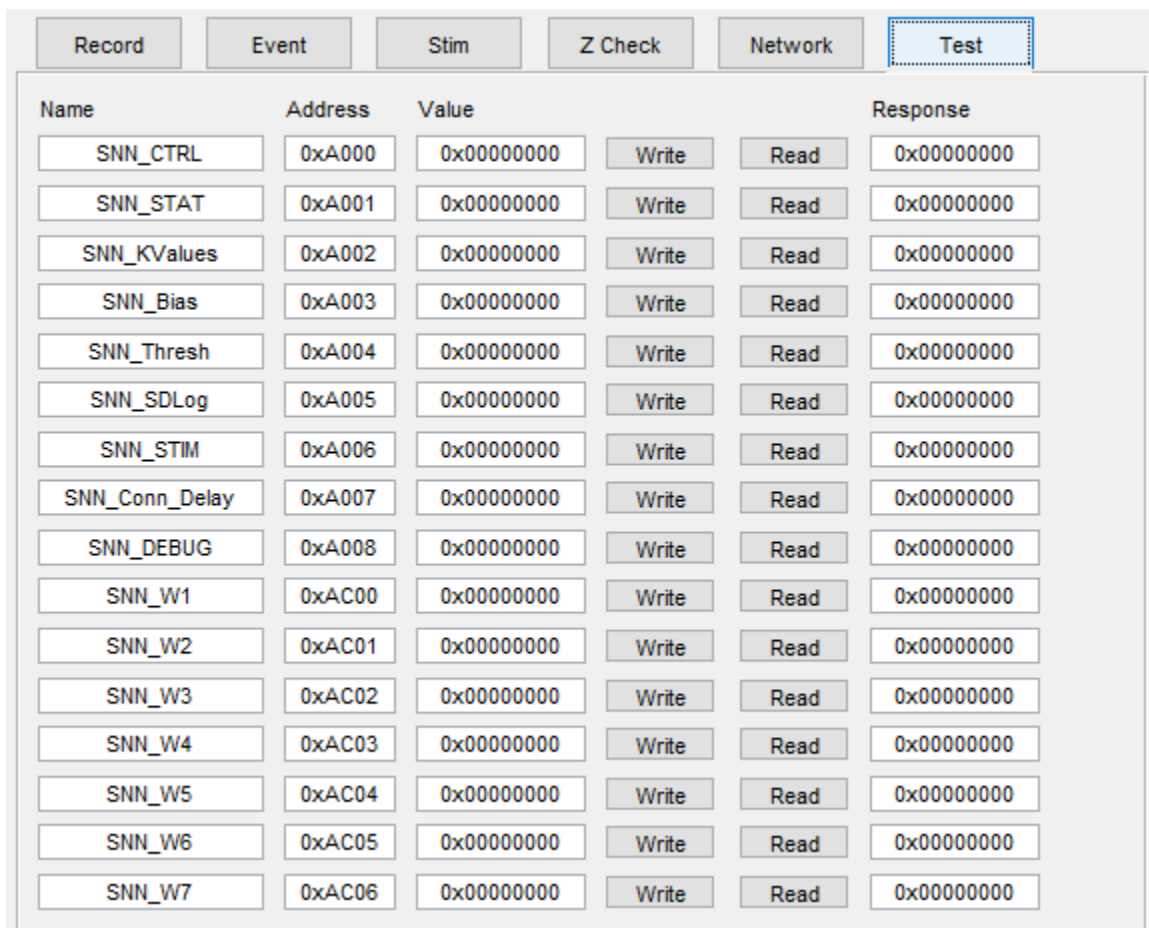


Figure 2. Unit potential calculation. Spiking input from connected units will sum into a target unit's potential. If a unit's potential reaches threshold it will be reset to 0 and the unit will send a spike to all of its target units. The spike will cause a Post Synaptic Potential proportional to W_{ij} . This PSP may be excitatory or inhibitory depending on the sign of W_{ij} .

The Test Panel

The Test Panel is used for debugging purposes only. Normally it is disabled and does not appear in the user interface at all. It can, however, be enabled by a small edit at the beginning of the nc326.c script by changing the variable `ui.show_test_tab` from its default value of 0 to a new value of 1.

This panel allows registers on the FPGA to be inspected and set in order to verify correct operation of FPGA code blocks. There is a separate document (`Spec_nc3d_0x0E.docx`) which details the operation of these blocks and the registers settings associated with them.

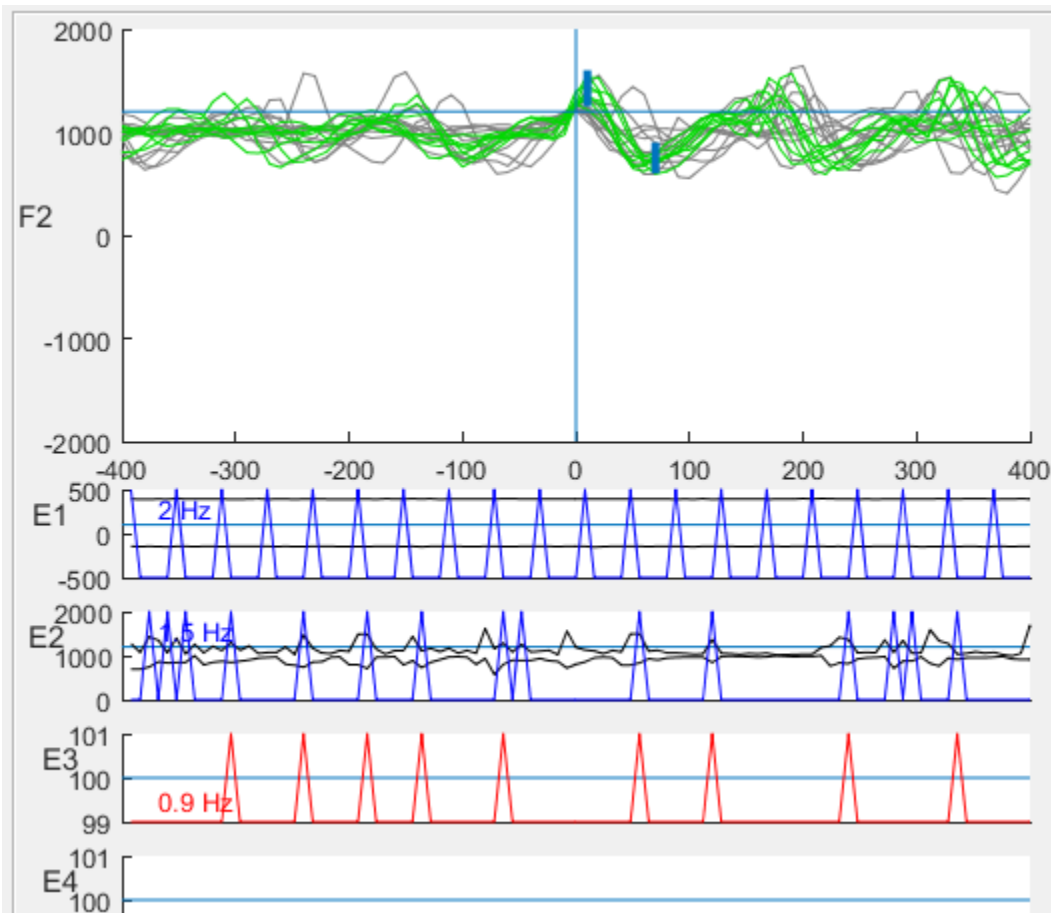


The screenshot shows a software interface with a top navigation bar containing buttons for 'Record', 'Event', 'Stim', 'Z Check', 'Network', and 'Test'. The 'Test' button is highlighted with a dashed border. Below the navigation bar is a table with the following columns: Name, Address, Value, Write, Read, and Response. The table lists 18 registers, all with a value of 0x00000000. Each row has 'Write' and 'Read' buttons next to the Value column, and a 'Response' column with a text box containing the current value.

Name	Address	Value	Write	Read	Response
SNN_CTRL	0xA000	0x00000000	Write	Read	0x00000000
SNN_STAT	0xA001	0x00000000	Write	Read	0x00000000
SNN_KValues	0xA002	0x00000000	Write	Read	0x00000000
SNN_Bias	0xA003	0x00000000	Write	Read	0x00000000
SNN_Thresh	0xA004	0x00000000	Write	Read	0x00000000
SNN_SDLog	0xA005	0x00000000	Write	Read	0x00000000
SNN_STIM	0xA006	0x00000000	Write	Read	0x00000000
SNN_Conn_Delay	0xA007	0x00000000	Write	Read	0x00000000
SNN_DEBUG	0xA008	0x00000000	Write	Read	0x00000000
SNN_W1	0xAC00	0x00000000	Write	Read	0x00000000
SNN_W2	0xAC01	0x00000000	Write	Read	0x00000000
SNN_W3	0xAC02	0x00000000	Write	Read	0x00000000
SNN_W4	0xAC03	0x00000000	Write	Read	0x00000000
SNN_W5	0xAC04	0x00000000	Write	Read	0x00000000
SNN_W6	0xAC05	0x00000000	Write	Read	0x00000000
SNN_W7	0xAC06	0x00000000	Write	Read	0x00000000

The Data Displays

The right hand panel on the GUI is dedicated to data displays for the eight event generators. These displays can show sweeps of data for the currently selected event generator, as well as monitoring summary activity on all event generators. A sweep can be generated by a threshold crossing for a discriminated source signal, or by a periodic event occurrence, but only about 1 sweep per second can be downloaded through the infrared serial adapter. Below the sweep display are plots for each of the eight event generators where summary (minimum and maximum data values), events, and stimulations are displayed in 100mS bins. Data is shown in block, events are shown in blue, and stimulations in red.



The Data Displays are active only when the Connect button is active and the corresponding event generators are turned on. Updates occur about once per second over the infrared serial adapter. If the selected event generator is setup to discriminate a source signal, then sweeps for that source will be displayed in green if Matlab projects that the sweep would have been accepted by both discriminator windows.