Specification for the NEV and NSx file formats (Rev. 2.2)

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File Format Overview

There are two different file formats to save digitized intracellular electrode spike and continuously sampled information:

- The *.NEV files contain digitized extracellular electrode spike information
- The *.NS1, *.NS2, *.NS3, *.NS4 and *.NS5 files contain digitized continuously sampled information (e.g. local field potentials (LFPs) or electromyograms (EMGs))

NEV File Format

This data format is designed to provide a method for encoding digitized extracellular electrode spike information for up to 255 electrodes (future revisions of the specification will provide higher counts). The format also includes methods for embedding low bandwidth, time-stamped experiment events. This format represents a balance between format flexibility to encode a variety of different event types, efficiency of encoding, and simplicity of organization for quick analysis.

A ***.NEV** file is composed of three sections:

1) **Header Basic Information**
   A series of fixed width fields containing the basic timing, creation, and comment information of the file.
2) **Header Extended Information**
   A variable number of fixed-width packets which can be used to embed data about the configuration of certain electrode channels and other important experiment information. File spec 2.2 adds the following extended header types: NEUEVLBL, NEUEVFLT and DIGLABEL
3) **Data Packets**
   A series of fixed width packets used to encode the electrode data stream.

All data stored in the file is in the form of packets that encapsulate information about certain events. For example, a spike on an electrode is considered to be an event, and the time of the spike, the channel number, and the waveform of the spike are stored in a data packet. Non-neural experiment events can also be embedded as data packets. Electrode channels in the file are numbered from 1 to 255. All data is written in a time non-decreasing manner.

Section 1 - Header Basic Information

This section is placed at the beginning of the file and consists of the following fields in the order listed.

NEURALEV

Field	Type	Length (Bytes)	Description
File Type ID	Char array	8	Always set to "**NEURALEV**" for "neural events".
File Spec	2 x unsigned char	2	The major and minor revision numbers of the file specification used to create the file e.g. use 0x0201 for Spec. 2.1.
Additional Flags	Unsigned int-16	2	File format additional flags. Bit 0: Set if all spike waveform values in the file are 16-bit; cleared if a mixture is to be expected. In the cleared case you MUST look at **NEUEVWAV** to determine the number of bytes per waveform sample. In the set case, **NEUEVWAV** may still be read, as all **NEUEVWAV** headers will indicate 16-bit data. All other bits are reserved and should be set to 0.
Bytes in Headers	Unsigned int-32	4	The total number of bytes in both headers (Standard and Extended). This value can also be considered to be a zero-indexed pointer to the first data packet.
Bytes in Data Packets	Unsigned int-32	4	The length (in bytes) of the fixed width data packets in the data section of the file. The packet sizes must be between 12 and 256 bytes (see Data Section description). Packet sizes are required to be multiples of 4 so that the packets are well aligned for 32-bit file access.
Time Resolution of Time Stamps	Unsigned int-32	4	This value denotes the frequency (counts per second) of the global clock used to index the time samples of the individual data packet entries.
Time Resolution of Samples	Unsigned int-32	4	This value denotes the sampling frequency (counts per second) used to digitize neural waveforms.
Time Origin	Windows SYSTEM TIME structure	16	The Local Time at which the data in the file was collected. This also corresponds to time index zero for the time stamps in the file. The structure consists of eight 2-byte unsigned int-16 values defining the Year, Month, DayOfWeek, Day, Hour, Minute, Second, and Millisecond.
Application to Create File	String - Char array	32	A 32 character string labeling the program which created the file. Programs should also include their revision number in this label. The string must be null terminated.
Comment Field	String - Char array	256	A 256 character, null-terminated string used for embedding comments into the data field. Multi-line comments should ideally use no more than 80 characters per line and no more than 8 lines. The string must be NULL terminated.
Number of Extended Headers	Unsigned int-32	4	A long value indicating the number of extended header entries.

Section 2 - Header Extended Information

This section consists of a variable number of 32-byte, fixed length extended information entries. The exact number of entries in this section is specified at the end of the Header Basic Information section. These entries may be used to include additional configuration information and comments into the file.

Each 32-byte extended information entry consists of an **8 byte identifier** and a **24 byte information field**. These entries are not required to be of any registered type. For example, a program can add extended header entries to the NEV file that only the program or related programs can utilize. However, there are several standard entries and identifiers that are defined in the specification and listed below with the 8 character identifier and 24 byte information field.

ARRAYNME

Field	Type	Length (Bytes)	Description
Packet ID	Char array	8	Always set to "**ARRAYNME**" for "array name".
Electrode Array Name	String - char array	24	String name of the electrode array used, Must be null-terminated.

ECOMMENT

Field	Type	Length (Bytes)	Description
Packet ID	Char array	8	Always set to "**ECOMMENT**" for "extra comment".
Extra Comment	String - Char array	24	String name to be included, must be null-terminated.

CCOMMENT

Field	Type	Length (Bytes)	Description
Packet ID	Char array	8	Always set to "**CCOMMENT**" for "continued comment".
Continued Comment	String - Char array	24	String to be appended to previous comment, must be null-terminated.

MAPFILE

Field	Type	Length (Bytes)	Description
Packet ID	Char array	8	Always set to "**MAPFILE**" + NULL
Mapfile	String - Char array	24	Mapfile used in the creation of the data, must be null-terminated.

NEUEVWAV

Field	Type	Length (Bytes)	Description
Packet ID	Char array	8	Always set to "**NEUEVWAV**" for a standard "neural event waveform".
Electrode ID	Unsigned int-16	2	Electrode ID number used in the data section of the file (1-255). Also used in NEUEVLBL and NEUEVFLT.
Physical Connector	Unsigned char	1	Physical system connector or module connected to the electrode (e.g. Front-End Bank A, B, C, D are 1, 2, 3, 4).
Connector Pin	Unsigned char	1	Physical system connector pin or channel connected to the electrode (e.g. 1-37 on bank A, B, C, D).
Digitization Factor	Unsigned int-16	2	Digitization scaling factor (nV per LSB step).
Energy Threshold	Unsigned int-16	2	Energy threshold, 0 if none used.
High Threshold	Int-16	2	Amplitude high threshold used (in µV) 0 to 32767.
Low Threshold	Int-16	2	Amplitude low threshold used (in µV) 0 to -32767.
Number of Sorted Units	Unsigned char	1	Number of sorted units in channel, set to 0 for no unit classification.
Bytes per Waveform	Unsigned char	1	Number of bytes per waveform sample, a value of 0 or 1 indicates 1 byte; 2 indicates 2 bytes; 3 indicates 3 bytes; etc.
			Remaining bytes reserved, write as zero.

NEUEVLBL (does NOT apply to file spec 2.1)

Field	Type	Length (Bytes)	Description
Packet ID	Char array	8	Always set to "**NEUEVLBL**" for a standard "neural event Label".
Electrode ID	Unsigned int-16	2	Electrode ID number used in the data section of the file (1-255). Also used in NEUEVWAV and NEUEVFLT.
Label	String – Char array	16	Label of this electrode. Must be NULL terminated
		6	Remaining bytes reserved, write as zero.

NEUEVFLT (does NOT apply to file spec 2.1)

Field	Type	Length (Bytes)	Description
Packet ID	Char array	8	Always set to "**NEUEVFLT**" for a standard "Neural Event Filter".
Electrode ID	Unsigned int-16	2	Electrode ID number used in the data section of the file (1-255). Also used in NEUEVWAV and NEUEVLBL.
High Freq Corner	Unsigned int-32	4	High frequency cutoff in mHz of the source signal filtering.
High Freq Order	Unsigned int-32	4	Order of the filter used for high frequency cutoff. 0 = NONE
High Filter Type	Unsigned int-16	2	Type of filter used for high frequency cutoff: 0 = None, 1 = Butterworth.
Low Freq Corner	Unsigned int-32	4	Low frequency cutoff in mHz of the source signal filtering.
Low Freq Order	Unsigned int-32	4	Order of the filter used for low frequency cutoff. 0 = NONE
Low Filter Type	Unsigned int-16	2	Type of filter used for low frequency cutoff: 0 = None, 1 = Butterworth
		2	Remaining bytes reserved, write as zero.

DIGLABEL (does NOT apply to file spec 2.1)

Field	Type	Length (Bytes)	Description
Packet ID	Char array	8	Always set to "**DIGLABEL**" for a standard "Digital Label"
Label	String – Char array	16	Label of the digital channel. Must be NULL terminated
Mode	Byte	1	0 = serial, 1 = parallel
		7	Remaining bytes reserved, write as zero.

NSASEXEV

Field	Type	Length (Bytes)	Description
Packet ID	Char array	8	Always set to "**NSASEXEV**". Configuration of NSAS experiment information channels
Frequency	Unsigned int-16	2	Frequency of periodic packet generation, 0 if none.
Digital Input Configuration	Unsigned char	1	Digital input port configuration: bit 0 = 0 if digital input port changed are ignored bit 0 = 1 if digital input port changes cause experiment information events bit 1-7 are reserved
Analog Channel 1 Configuration	Unsigned char	1	External analog channel 1 configuration: bit 0 = Low to High edge triggers experiment information event (0 = no, 1 = yes) bit 1 = High to Low edge triggers experiment information event (0 = no, 1 = yes)
Ch 1 Edge Detect Value	Int-16	2	Analog Channel 1 edge detect value in mV (-5000 to 5000).
Analog Channel 2 Configuration	Unsigned char	1	External analog channel 2 configuration: bit 0 = Low to High edge triggers experiment information event (0 = no, 1 = yes) bit 1 = High to Low edge triggers experiment information event (0 = no, 1 = yes)
Ch 2 Edge Detect Value	Int-16	2	Analog Channel 2 edge detect value in mV (-5000 to 5000).
Analog Channel 3 Configuration	Unsigned char	1	External analog channel 3 configuration: bit 0 = Low to High edge triggers experiment information event (0 = no, 1 = yes) bit 1 = High to Low edge triggers experiment information event (0 = no, 1 = yes)
Ch 3 Edge Detect Value	Int-16	2	Analog Channel 3 edge detect value in mV (-5000 to 5000).
Analog Channel 4 Configuration	Unsigned char	1	External analog channel 4 configuration: bit 0 = Low to High edge triggers experiment information event (0 = no, 1 = yes) bit 1 = High to Low edge triggers experiment information event (0 = no, 1 = yes)
Ch 4 Edge Detect Value	Int-16	2	Analog Channel 4 edge detect value in mV (-5000 to 5000).
Analog Channel 5 Configuration	Unsigned char	1	External analog channel 5 configuration: bit 0 = Low to High edge triggers experiment information event (0 = no, 1 = yes) bit 1 = High to Low edge triggers experiment information event (0 = no, 1 = yes)
Ch 5 Edge Detect Value	Int-16	2	Analog Channel 5 edge detect value in mV (-5000 to 5000).
		6	Remaining bytes reserved, write as zero.

Section 3 - Data Packets

This section contains an unspecified number of fixed length data. Extracellular spike events and external experiment channel updates are stored in these packets.

Each packet begins with a **4 byte (unsigned long) Time Stamp** and a **2 byte (word) Packet Identifier**. The remaining bytes of the packet are defined according to the packet type.

The 2 byte (word) Packet Identifier determines the information stored in the remainder of the packet. The different IDs correspond to system events or events on certain electrodes. In this revision of the specification, only packet IDs from 0 to 255 are valid. The upper 8 bits of this value are reserved as 0.

Packet Identifier 0

Represent packets that give the state of non-neural experiment information channels. These packets can be inserted whenever a periodic sampling timer expires, the value of the digital input port changes, or when an analog edge threshold is crossed.

This revision provides for digital values up to 16 bits, and 5 analog inputs to be logged for each experiment information entry. An event trigger on any one of the experiment information channels is assumed to log the instantaneous state of all of the experiment information channels.

The data fields of packets with Packet ID 0 are (in order):

Field	Type	Length (Bytes)	Description
Timestamp	Unsigned int-32	4	Time at which event occurred. A time stamp of zero corresponds to the beginning of the data acquisition cycle. The frequency of the time stamp clock and the time of the file creation are stored in the file header.
Packet ID	Unsigned int-16	2	Equal to zero.
Packet Insertion Reason	Unsigned char	1	Bit flag field detailing why this packet was inserted: bit 0 set if digital channel changed bit 1 set if analog channel 1 crossed threshold bit 2 set if analog channel 2 crossed threshold bit 3 set if analog channel 3 crossed threshold bit 4 set if analog channel 4 crossed threshold bit 5 set if analog channel 5 crossed threshold bit 6 set if periodic sampling event bit 7 set if serial channel changed (**bit 0 must be set as well**) (multiple bits may be set)
Reserved	Unsigned char	1	Reserved for future unit information (use 0).
Digital Input	Unsigned int-16	2	Value of the digital input port.
Input Ch 1	Int-16	2	Analog input channel 1 value in mV (± 5000).
Input Ch 2	Int-16	2	Analog input channel 2 value in mV (± 5000).
Input Ch 3	Int-16	2	Analog input channel 3 value in mV (± 5000).
Input Ch 4	Int-16	2	Analog input channel 4 value in mV (± 5000).
Input Ch 5	Int-16	2	Analog input channel 5 value in mV (± 5000).

Packet Identifiers to 1 through 255

Represent a spike event on the electrode number given by the packet ID number. For example, a data packet with ID 25 indicates that a spike occurred on electrode 25 at the time of the time stamp. The data fields of packets with Packet ID 1-25 are (in order):

Field	Type	Length (Bytes)	Description
Timestamp	Unsigned int-32	4	A time stamp of zero corresponds to the beginning of the data acquisition cycle. The frequency of the time stamp clock and the time of the file creation are stored in the file header.
Packet ID	Unsigned int-16	2	Electrode ID number (1-255). Also used in NEUEVWAV, NEUEVLBL and NEUEVFLT.
Unit Classification Number	Unsigned char	1	Unit classification number for the spike event: 0 = unclassified 1-16 = units 1 through 16 17 - 254 = reserved 255 = "noise"
Reserved	Unsigned char	1	Reserved for future unit information (use 0).
Waveform	Char array	Packet_ width – 8	The sampled waveform of the spike.

Continuation Packets

If the time stamp of the packet is 0xFFFFFFFF, the remaining bytes of the packet are a continuation of the previous packet and should be appended to that packet. This is to provide support for future revisions in which the packet size may be allowed to shrink to 8 characters wide (no event waveform storage). In this case, the continuation packets would be used to squeeze packets (such as external info packets) which would not fit into an 8 character wide format.

NSx File Format

In addition to the .NEV file described above, there can also be extended nev files. These files have the extension .NSx where *x* is some number between 1 and 9. This file is used to store information for channels which are sampled continuously, e.g. LFP recordings. All data is written in a time non-decreasing manner.

A file with the extension .NSx most likely is accompanied by a .NEV file with the same base name: for instance, *data.nev* and *data.ns2*. Please note, the existence of a single extended nev file does neither require, nor preclude the existence of other extended nev files. Moreover, the extended nev files will not necessarily start with .ns1; the combination of *data.nev* and *data.ns2* is perfectly valid. The existence of two extended nev files indicates that continuous channel sampling occurred at two data rates; for instance, 500 S/s and 1 kS/s.

Section 1a – Basic Header (file spec 2.1)

The file begins with a file header. All Char arrays are **not** guaranteed to be 0 terminated; they will be **only** if the string is actually shorter than the maximum length allowed. All multi-byte data types will be stored in little-endian format.

Field	Type	Length (Bytes)	Description
File ID	Char array	8	Always set to "**NEURALSG**" for Neural Sample Group '0' terminated **only** if fewer chars than allocated
Label	Char array	16	Label of the sampling group e.g. 1 kS/s or LFP Low '0' terminated **only** if fewer chars than allocated
Period	Unsigned int-32	4	Number of 1/30,000 seconds between data points e.g. sampling rate of 30 kS/s = 1; 10 kS/s = 3
Channel Count	Unsigned int-32	4	Number of channels per data point
Channel ID	Array of unsigned int-32	Variable (4 bytes per chan)	Electrode number for each channel being sampled and data saved. This number will correspond exactly with the "electrode number" of section 3. There will be exactly "Channel Count" number of entries in this field.

Section 1b – Basic Header (file spec 2.2)

The file begins with a file header. All char arrays are **not** guaranteed to be 0 terminated; they will be **only** if the string is actually shorter than the maximum length allowed. All multi-byte data types will be stored in little-endian format.

NEURALCD

Field	Type	Length (Bytes)	Description
File Type ID	Char array	8	Always set to "**NEURALCD**" for "Neural Continuous Data". Note: In prior versions of the file, this field was set to "NEURALSG".
File Spec	2 x unsigned char	2	The major and minor revision numbers of the file specification used to create the file e.g. use 0x0202 for Spec. 2.2.
Bytes in Headers	Unsigned int-32	4	The total number of bytes in both headers (Standard and Extended). This value can also be considered to be a zero-indexed pointer to the first data packet.
Label	Char array	16	Label of the sampling group e.g. "1 kS/s" or "LFP Low". **Must** be '0' terminated.
Comment	Char array	256	Comment about the file. **Must** be '0' terminated
Period	Unsigned int-32	4	Number of 1/30,000 seconds between data points e.g. sampling rate of 30 kS/s = 1; 10 kS/s = 3
Time Resolution of Time Stamps	Unsigned int-32	4	This value denotes the frequency (counts per second) of the global clock used to index the time samples of the individual data packet entries.
Time Origin	Windows SYSTEM TIME structure	16	The Greenwich Mean Time at which the data in the file was collected. This also corresponds to time index zero for the time stamps in the file. The structure consists of eight 2-byte unsigned int-16 values defining the Year, Month, DayOfWeek, Day, Hour, Minute, Second, and Millisecond.
Channel Count	Unsigned int-32	4	Number of channels per data point. This will also match the number of extended headers.

Section 2 - Extended Headers (file spec 2.2)

The exact number of entries in this section is specified by the Channel Count in the basic file header. These entries are used to include indicate which channels were recorded and what their configuration was. Additional extended headers such as comments might be added in the future.

CC

Field	Type	Length (Bytes)	Description
Type	Char array	2	Always set to "**CC**" for "Continuous Channels"
Electrode ID	Unsigned int-16	2	Electrode number being sampled and data saved. This number will correspond exactly with the "electrode number" of the *.NEV file.
Electrode label	String - Char array	16	Label or name of the electrode (e.g. "elec1"). Must be NULL terminated.
Physical Connector	Unsigned int-8	1	Physical system connector or module connected to the electrode (e.g. Front-End Bank A, B, C, D are 1, 2, 3, 4).
Connector Pin	Unsigned int-8	1	Physical system connector pin or channel connected to the electrode (e.g. 1-37 on bank A, B, C, D).
Min Digital Value	Int-16	2	Minimum digital value of the signal (e.g. -8192).
Max Digital Value	Int-16	2	Maximum digital value of the signal (e.g. 8192).
Min Analog Value	Int-16	2	Minimum analog value of the signal (e.g. -5000 mV).
Max Analog Value	Int-16	2	Maximum analog value of the signal (e.g. 5000 mV).
Units	String - Char array	16	Units of the analog range values ("mV", "µV"). Must be NULL terminated
High Freq Corner	Unsigned int-32	4	High frequency cutoff in mHz of the source signal filtering.
High Freq Order	Unsigned int-32	4	Order of the filter used for high frequency cutoff: 0 = NONE
High Filter Type	Unsigned int-16	2	Type of filter used for high frequency cutoff: 0 = NONE, 1 = Butterworth
Low Freq Corner	Unsigned int-32	4	Low frequency cutoff in mHz of the source signal filtering.
Low Freq Order	Unsigned int-32	4	Order of the filter used for high frequency cutoff: 0 = NONE
Low Filter Type	Unsigned int-16	2	Type of filter used for high frequency cutoff: 0 = NONE, 1 = Butterworth

Immediately following the header will be the "data" section.

Section 3a – Data Packets (file spec 2.1)

Each entry in the data section corresponds to a single point in time, and the entries are in order of increasing time. Each entry consists of the samples from multiple channels and is defined as follows:

Field	Type	Length (Bytes)	Description
Data point	Array of signed int-16	Variable (2 bytes per chan)	This corresponds to a single data collection point There will be exactly "Channel Count" number of data points. They will be sorted in the same order as they are presented in "Channel ID".

Section 3b – Data Packets (file spec 2.2)

This section contains an sections starting by a header, a timestamp, the number of data points and an unspecified number of data points.

Timestamps indicate the starting time for the data block that follows. Timestamps will be inserted at the beginning of a data file or additionally to indicate a gap, e.g. when a file has been paused. A timestamp is followed by a varying number of data point entries indicated by the number of data points. Data points are corresponding to a single point in time. The entries are in order of increasing time. Each entry consists of the samples from multiple channels.

0x01

Field	Type	Length (Bytes)	Description
Header	Byte	1	Always set to 0x01.
Timestamp	Unsigned int-32	4	A time stamp of zero corresponds to the beginning of the data acquisition cycle. The frequency of the time stamp clock and the time of the file creation are stored in the file header.
Number of Data Points	Unsigned int-32	4	Number of data points following this header.
Data Point	Array of int-16	Variable (2 bytes per channel)	This corresponds to a single data collection point There will be exactly "Channel Count" number of data points. They will be sorted in the same order as they are presented in "Channel ID". Data will be stored as digital values.

Revision History

Version 3.0 Combined information for file spec 2.1 and file spec 2.2 into one document.

Small editorial changes.

Version 2.2 Changed file format of .NSx data files to allow pausing.
Added extended header with channel configurations to .NSx files to make them standalone.
Changed presentation of .NEV data file format.
Added NEUEVLBL
Added NEUEVFLT

Version 2.1 Added serial data flag (BIT-7 of Packet ID 0 of Section 3)
Added description of the .NSx data files

Version 2.0 First major revision to the file format. The X-Y channel notation system was scrapped in favor of a 1-255 straight linear numbering scheme. It is recommended that newer NEV programs only use this format and older NEV files be converted to NEV version 2.0 files. The types of packets have also been simplified into the 2 most commonly used entries in this format, neural events and external events. NSASEXEV and external events were also change to mV representation.