Specification for the TOC file format (Rev. 1.1)

Contents:

File Format Overview

There are several different file formats. Their uses are explained below:

- The *.TOC files list exactly which files belong to a particular recording; in other words, an index.
- The *.SIF files contain details about a particular session. E.g. patient name
- 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))

TOC File Format

This data format is the Table Of Contents for the files associated with a recording session. The data is in XML format for ease of readability.

The root XML key is <TOC> and contains 2 sections:

1) <Global> - Global version information and location of the SIF file.
2) <File> - Files comprising the complete recording session.

Section 1 – Global Information

This section contains global version information and the location of the session information file (SIF). The data is in XML format under the root TOC key and contains:

1. <SpecVersion> - This is the version of the TOC spec that the data in this file represents.
2. <AppVersion> - This is the version of the Application that created this file.
3. <SessionInfo> - This is the relative path to the location of the Session Information File (*.SIF). The path is relative to this file (*.TOC)

Section 2 – File Information

This section contains details of the set of files comprising the recording session. Each set starts at the same point in time. Each set consists of a single NEV file and zero to multiple NSx files.

1. <NEVxxx> - The NEV files are contained in a key starting with NEV followed by a three digit number (xxx) indicating the position within the file set increasing in value and starting with 001.
2. <NSyxxx> - The NSx files are contained in keys starting with NS followed by a one digit number (y) indicating the count of NSx files increasing in value and starting with 1. This is then followed by a three digit number (xxx) indicating the position within the file set increasing in value and starting with 001 which corresponds with the value of the NEV file which starts at the same time index.

SIF File Format

This data format is the Session Information File which contains institution and patient information. The data is in XML format.

The root XML key is <SIF> and contains 2 sections:

1. <Institution> - Details of the institution where the recording was performed.
2. <Patient> - Details about this patient.

Section 1 – Institution Information

This is a sub key which contains specifics about the institution.

1. <Name> - This sub key of Institution contains the name of the institution.

Section 2 – Patient Information

This is a sub key which contains specifics about the patient.

2. <Id> - This data key contains the patient id.
3. <Name> - This is a sub key which contains data keys which comprise the patient's name.
    a. <First> - This data key contains the patient's first name.
    b. <Middle> - This data key contains the patient's middle Initial.
    c. <Last> - This data key contains the patient's last name.
4. <Birthday> - This is a sub key which contains data keys which comprise the patient's birthday.
    a. <Month> - This data key contains the patient's month of birth.
    b. <Day> - This data key contains the patient's day of birth.
    c. <Year> - This data key contains the patient's year of birth.

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.
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 be 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.

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.

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

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

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 NEUEVBL.
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

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 1 – Basic Header

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.

NEURALSG

Field	Type	Length (Bytes)	Description
File Type 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.

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

Section 2 – Data Packets

Each entry consists of 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.

Data Packet

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". Data will be stored as digital values.

NIX File Format

In addition to the .NEV and .NSx files described above, there can also be an optional index file. This file has the extension .NIX. This file is used to store index information for segment and neural data. All data for each segment or neural entity is written in a time non-decreasing manner.

Section 1 – Basic Header

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.

NEURALIX

Field	Type	Length (Bytes)	Description
File Type ID	Char array	8	Always set to "NEURALIX" for Neural Index '0' terminated **only** if fewer chars than allocated
Bytes in Headers	Unsigned int-64	8	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.
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 40-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.

FILECAT

Field	Type	Length (Bytes)	Description
Packet ID	Char array	8	Always set to "**FILECAT**" for a standard "File Catalog" '0' terminated **only** if fewer chars than allocated
File ID	Unsigned int-16	2	File ID number used in the data section of the file.
File Name	Char array	24	Filename in the format yyyymmdd-hhmmss-###.nev where ### is the file number in the set in increasing order. '0' terminated **only** if fewer chars than allocated

EVENTIDX

Field	Type	Length (Bytes)	Description
Packet ID	Char array	8	Always set to "**EVENTIDX**" for a standard "Event Index" '0' terminated **only** if fewer chars than allocated
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)
Item Count	Unsigned int-32	4	Number of events associated with the reason specified in Packet Insertion Reason
Offset	Unsigned int-64	8	Offset from the beginning of the data section (Bytes in Headers) of index data for Electrode ID. **Note**: Unit Classification Number data is interspersed within the index data for Electrode ID
		11	Remaining bytes reserved, write as zero.

ELECTIDX

Field	Type	Length (Bytes)	Description
Packet ID	Char array	8	Always set to "**ELECTIDX**" for a standard "Electrode Index" '0' terminated **only** if fewer chars than allocated
Electrode ID	Unsigned int-16	2	Electrode ID number used in the data section of the file (1-255).
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"
Item Count	Unsigned int-32	4	Number of events associated with Electrode ID and Unit Classification Number
Offset	Unsigned int-64	8	Offset within this index file to the beginning of index data for Electrode ID. Unit Classification Number data is interspersed within the index data for Electrode ID
		11	Remaining bytes reserved, write as zero.

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

Section 3 – Data Packets

This section contains an unspecified number of fixed length data. Packets are organized by Packet ID then by Timestamp in increasing order. File offsets to the data packets of non-neural and neural events 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 index of non-neural experiment information channels.

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

Field	Type	Length (Bytes)	Description
Timestamp	Double	8	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 Value	Unsigned int-16	2	Value of the digital input port.
		8	Remaining bytes reserved, write as zero.

Packet Identifier 1 through 255

Represent packets that give the index of spike events on the electrode number given by the packet ID number. The data fields of packets with Packet ID 1-255 are (in order):

Field	Type	Length (Bytes)	Description
Timestamp	Double	8	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	Electrode ID number (1-255).
Unit Classification Number	Unsigned char	1	Unit classification number for the 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).
File ID	Unsigned int-16	2	File number corresponding to the File Catalog entry which contains the data represented by this packet.
Data Packet Offset	Unsigned int-64	8	Offset of the data packet within the file identified by File ID.

Revision History

Version 1.1 Added index file specification.

Version 1.0 First release of the TOC file format.