Tucker-Davis Technologies
New Frontiers in Neuroscience

TDT to MATLAB:
Offline Analysis Tools

Introduction

TDT provides a set of cross-platform tools for reading TDT data files directly into MATLAB offline. It is compatible with Matlab 2007b and greater. The latest version can be downloaded here:
https://www.tdt.com/support/examples/TDTMatlabSDK.zip

For more complete examples, start here: https://www.tdt.com/support/sdk-offline.html

To begin, set MATLAB's current folder to the location of TDTbin2mat.m, or add the SDK folders to your MATLAB path with the addpath command:

```
>> addpath(genpath('C:\TDT\TDTMatlabSDK'));
```

TDT Data Storage

Data collected or used by TDT software is stored in tanks—special directories on your hard drive. Each time you press 'Record' in Synapse, a new block is created within the tank. Within a block different stores can record different types of events at different rates. The blocks are special folders within the tank directories.

TDTbin2mat

TDTbin2mat is an all-in-one function for reading TDT data into MATLAB. It needs only one input, the block path.

```
>> data = TDTbin2mat('C:\TDT\Synapse\Tanks\Exp1-160921-120606\Sub1-160921-124036');
```

TDTbin2mat will return a structure containing all recorded data from that block, organized by type:

1. **epocs** are values stored with onset and offset timestamps that can be used to create time-based filters on your data. They can be created by Epoch Data Storage gizmos and stimulation gizmos, among others.
   - **a.** If Runtime Notes were enabled in Synapse, they will appear in data.epocs.Note. The notes themselves will be in data.epocs.Note.notes.
     See https://www.tdt.com/files/manuals/SynapseManual.pdf#RuntimeNotes.
2. **streams** are continuous single channel or multichannel recordings, like those stored by Stream Data Storage gizmo. The structure includes the data array and sampling rate.
3. **snips** are short snippets of data collected on a trigger. For example, action potentials recorded around threshold crossings in the PCA Spike Sorting gizmo, or fixed duration snippets recorded by the Strobe Store gizmo. This structure includes the waveforms, channel numbers, sort codes, trigger timestamps, and sampling rate.
4. **scalars** are similar to epocs but can be single or multi-channel values and only store an onset timestamp when triggered. These can be created by the Strobe Data Storage gizmo.

The returned structure also contains an **info** field with block start/stop times, duration, and information about the Subject, User, and Experiment that it came from (if the block was created in Synapse).

TDTbin2mat uses parameter value combinations to refine the imported data. To extract specific event types only, use the 'TYPE' option. For example, to import epocs and snippets only, use this:

```
>> data = TDTbin2mat('C:\TDT\OpenEx\Tanks\EXAMPLE\Block-1','TYPE',{'epocs','snips'})
```

Use the 'STORE' option to extract a particular data store by name, in this example a streaming event called PDec. Combine this with the 'CHANNEL' option to extract a single channel, in this case channel 2:

```
>> data = TDTbin2mat('C:\TDT\OpenEx\Tanks\EXAMPLE\Block-1','STORE','PDec','CHANNEL',2);
```

You can also filter by time, if you are only interested in portions of the recording, or if the entire recording won't fit into available memory (RAM) at one time. Use the 'T1' and 'T2' options to specify the start and stop time, in seconds, to retrieve from the block. This example reads only the second minute of the block into MATLAB:

```
>> data = TDTbin2mat('C:\TDT\OpenEx\Tanks\EXAMPLE\Block-1', 'T1', 60, 'T2', 120);
```

TDTbin2mat offers many more useful options that are described in its help documentation.

```
>> help TDTbin2mat
```

TDTfilter

TDTfilter applies advanced epoc filtering to extracted data. For example, if you only want to look at data around a certain epoc event, you will use TDTfilter to do this. See the Raster/PSTH example for a complete demonstration https://www.tdt.com/support/EXRaster_PSTH.html.

To only look at data around the epoc event timestamps, use a 'TIME' filter. In this example, data from 20ms before the *Levl* epoc to 50ms after the onset is retained.

```
>> data = TDTfilter(data, 'Levl', 'TIME', [-0.02, 0.07]);
```

To only look at data when an epoc was a certain value, use a 'VALUE' filter. In this example, only data when the *Freq* epoc was equal to 9000 or 10000 is retained.

```
>> data = TDTfilter(data, 'Freq', 'VALUES', [9000, 10000]);
```

If you want to look for a particular behavioral response that occurs sometime during the allowed time range, use the 'MODIFIERS' filter. In this example, only data when the *Freq* epoc was 10000 AND the *Resp* epoc had a value of 1 sometime during the *Freq* epoc is retained.

```
>> data = TDTfilter(data, 'Freq', 'VALUES', [10000]);
>> data = TDTfilter(data, 'Resp', 'MODIFIERS', [1]);
```

As you can see, for complex filtering the output from one call to TDTfilter can become the input to the next call to TDTfilter. If your data sets are large, or if you are iterating through many combinations of epoc variables, it is preferred to extract only the epocs and do all of the epoc filtering first to find the valid time ranges that match the filter, and then use this as the 'RANGE' input to TDTbin2mat to extract all events (including snips, streams) on only those valid time ranges.

```
>> data = TDTbin2mat(block_path, 'TYPE', {'epocs'});
>> data = TDTfilter(data, 'Freq', 'VALUES', [9000, 10000]);
>> data = TDTfilter(data, 'Levl', 'VALUES', [70, 80, 90]);
>> data = TDTfilter(data, 'Resp', 'MODIFIERS', [1]);
>> data = TDTbin2mat(block_path, 'RANGES', data.time_ranges);
```

SEV2mat

SEV2mat reads SEV files into a MATLAB structure. SEV files are created by the RS4 Data Streamer or by enabling the Discrete Files option when streaming continuous signals in Synapse. SEV files consist of a single channel of data per file, with a short header, so it is very fast to read them. TDTbin2mat will automatically call SEV2mat if it finds SEV files in the block directory. Like TDTbin2mat, it needs only one input: the block path.

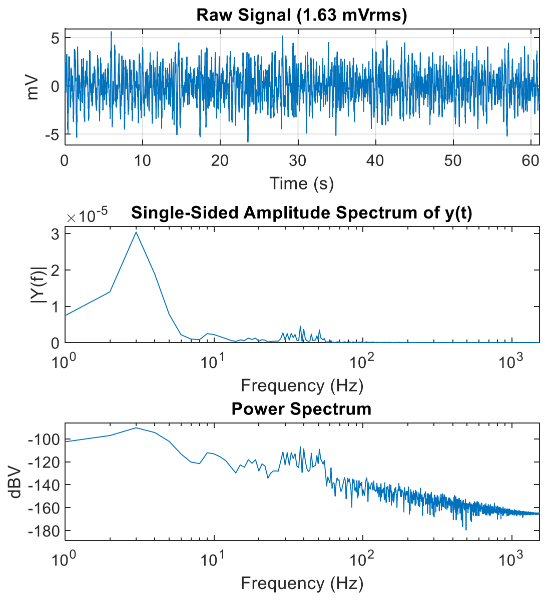
```
>> data = SEV2mat('C:\TDT\Synapse\Tanks\Exp1-160921-120606\Sub1-160921-124036');
```

SEV2mat will return a structure containing the streams that it found. Each stream field includes the data array and sampling rate.

TDTfft

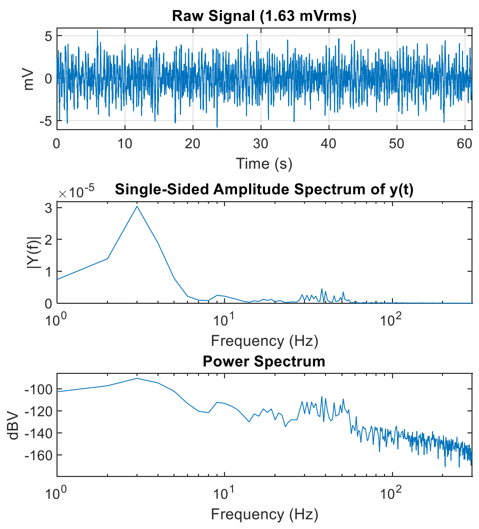
TDTfft performs frequency analysis on the data stream. It takes the stream data output of TDTbin2mat and a channel number as inputs. In this example, it is plotting channel 1 of the 'LFP1' store from an example block.

```
>> data = TDTbin2mat('C:\TDT\TDTExampleData\Algernon-180308-130351');
>> TDTfft(data.streams.LFP1, 1);
```



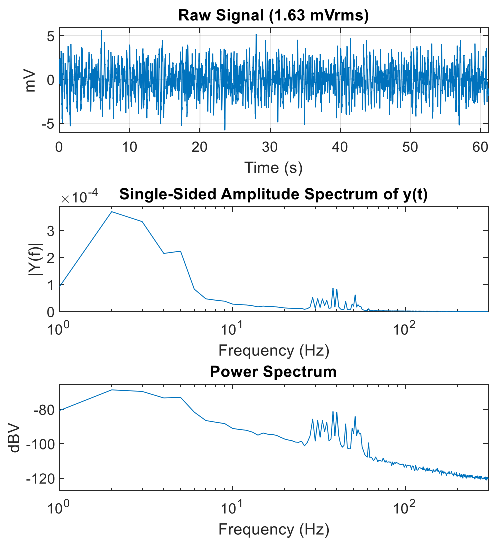
Use the ‘FREQ’ input to specify the frequency range that you’re interested in.

```
>> TDTfft(data.streams.LFP1, 1, 'FREQ', [0, 300]); % look at 0 to 300 Hz only
```



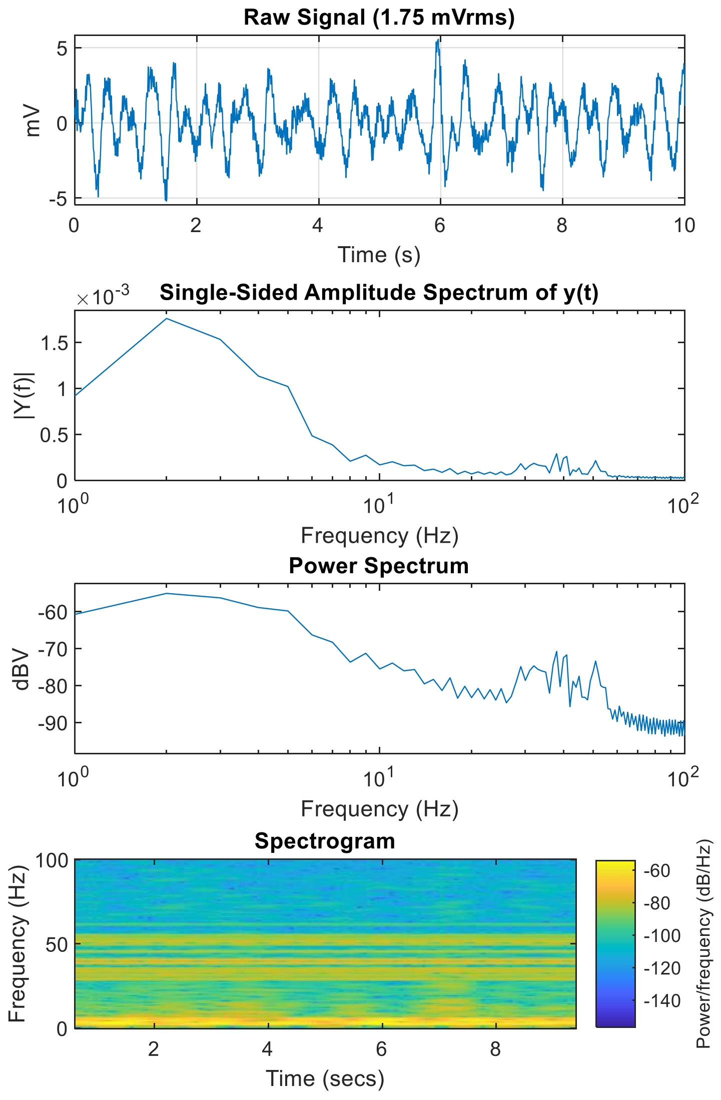
Often the frequency plot is noisy. Use the ‘NUMAVG’ input to smooth out the frequency plot and better isolate the components with the most power through the entire recording. This breaks the data into chunks, performs the FFT on those chunks, and then plots the average.

```
>> TDTfft(data.streams.LFP1, 1, 'FREQ', [0, 300], 'NUMAVG', 20); % average 20 chunks
```



Set the 'SPECPLOT' input to 1 to also display a spectrogram of the entire data stream. If the data set is too long then Matlab could run out of memory to do this, and you would need to use the T1 and T2 parameters in TDTbin2mat to look at smaller chunks of data.

```
>> data = TDTbin2mat('C:\TDT\TDTExampleData\Algernon-180308-130351', 'T2', 10);
>> TDTfft(data.streams.LFP1, 1, 'FREQ', [0, 100], 'NUMAVG', 20, 'SPECPLOT', 1);
```

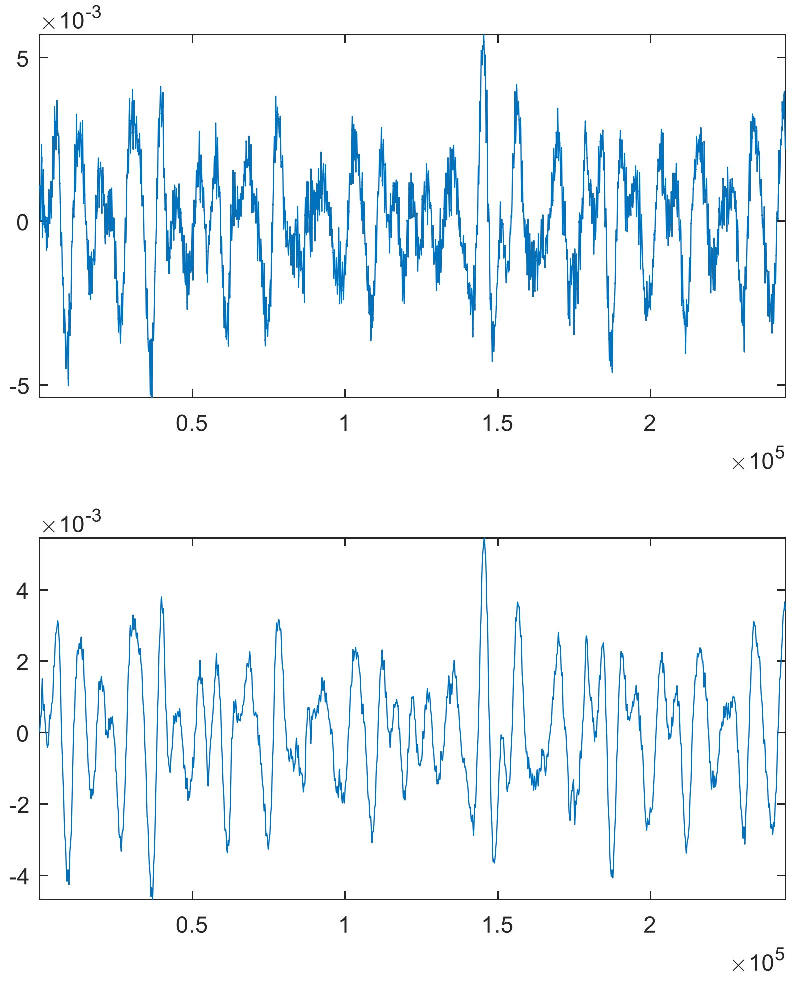


See the LFP plot example for more information (https://www.tdt.com/support/EXLFPPlot.html).

TDTdigitalfilter

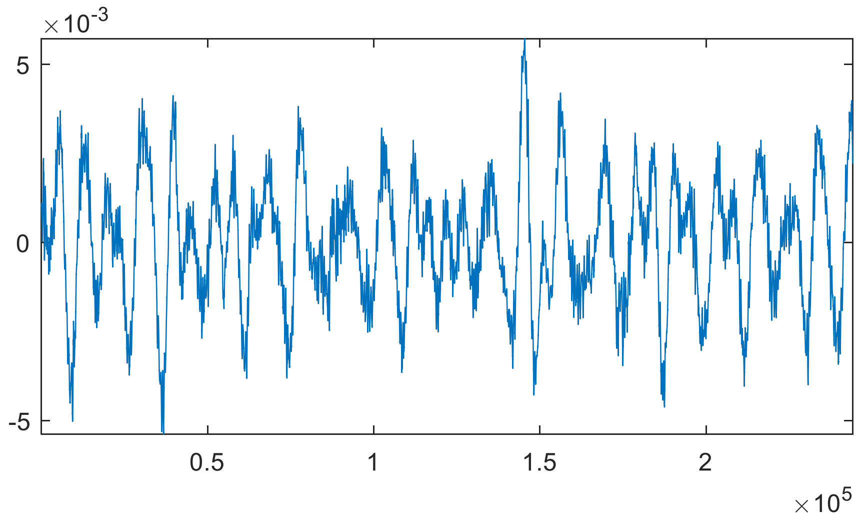
TDTdigitalfilter mimics the hardware digital filters in the Neural Stream Processor gizmo. It takes the output of TDTbin2mat and applies the specified digital filter to the specified streaming data store. Here is a simple 0-20Hz bandpass filter example:

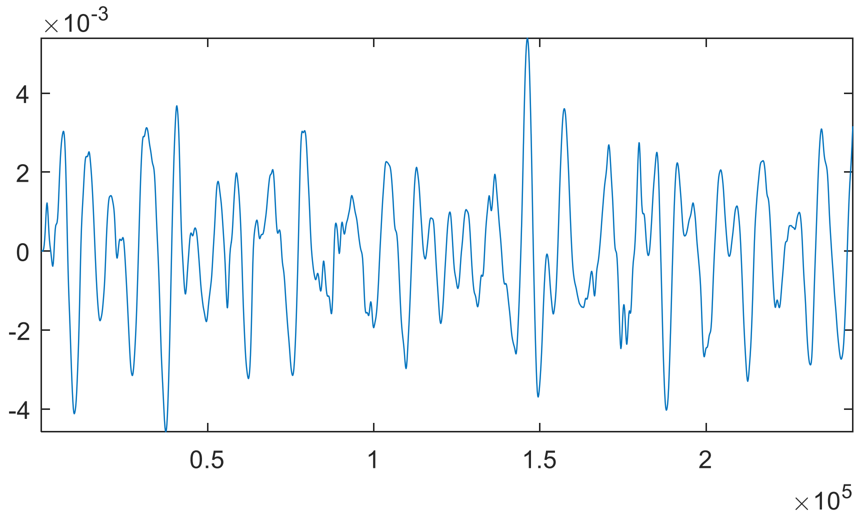
```
>> data = TDTbin2mat('C:\TDT\TDTExampleData\Algernon-180308-130351', 'T2', 10);
>> subplot(2,1,1);
>> plot(data.streams.Wav1.data(1,:));
>> data = TDTdigitalfilter(data, 'Wav1', [0, 20]); % look at 0-20 Hz only
>> subplot(2,1,2);
>> plot(data.streams.Wav1.data(1,:));
```



Use the 'ORDER' input to set the filter order. By default it is a 2 for a second order filter.

```
>> data = TDTdigitalfilter(data, 'Wav1', [0, 20], 'ORDER', 8);
```





You can also add a notch filter.

```
>> data = TDTdigitalfilter(data, 'Wav1', 'NOTCH', 60, 'ORDER', 4);
```

TDTthresh

TDTthresh takes continuous data and applies a thresholding algorithm to extract snippets. It has two modes, 'manual' and 'auto'. In 'manual' mode, supply the absolute threshold input ('THRESH') to extract snippets. Can be negative for negative-first spike detection.

In 'auto' mode, a multiple of the sliding RMS window is used to calculate the instantaneous threshold. Set the 'TAU' parameter to specify the time window, and set the 'STD' parameter to set the scalar. So if TAU=5 and STD=6, then the threshold will track 6*RMS of the previous 5 seconds.

The new snippet store generated from TDTthresh is called 'Snip'.

```
>> data = TDTbin2mat('C:\TDT\TDTExampleData\Algernon-180308-130351', 'T2', 10);
>> data = TDTdigitalfilter(data, 'Wav1', [300 5000]);
>> data = TDTthresh(data, 'Wav1', 'MODE', 'auto');
>> subplot(2,1,1);
>> plot(data.streams.Wav1.data(1,:));
>> subplot(2,1,2);
>> plot(data.snips.Snip.data');
```

You can set the 'TETRODE' flag to extract snippets organized by groups of 4 channels. If the threshold crosses on one channel, all 4 channels will get a snippet.

TDTthresh has a few more customizations you can explore in its help documentation.

```
>> help TDTthresh
```

See the Rethreshold example for a complete demonstration of TDTdigitalfilter and TDTthresh https://www.tdt.com/support/EXRethreshold.html.