aXona

Data acquisition systems for *in vivo* neuronal recording

Turnkey solutions for behavioral physiology

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Multi-channel data acquisition system

Introducing DacqUSB

DacqUSB (overview)

- Compact multi-channel data acquisition system designed to work with any PC having a USB 2.0 port.
- Designed for “tetrode” (twisted quadruple electrode) recording. During recording, spike events trigger data capture on all 4 channels in a group. The triggering can also be configured to record signals on pairs of channels (stereotrodes) or single independent electrodes as required.
- Amplifier modules support 16 channels each, and 4 modules can be accommodated in a single unit, for a total of 64 channels.
- Easy software selection and routing of signal and reference channels.
- Low frequency signals such as EEG can also be recorded on all channels.
- An integrated or external video tracker can be synchronised with unit recording so that spike events can be correlated with position events.
- A digital input module also allows unit recording to be coupled to other kinds of ongoing recording (such as lever-pressing). An opto-isolated digital output module allows DacqUSB to control experimental apparatus such as Skinner boxes.

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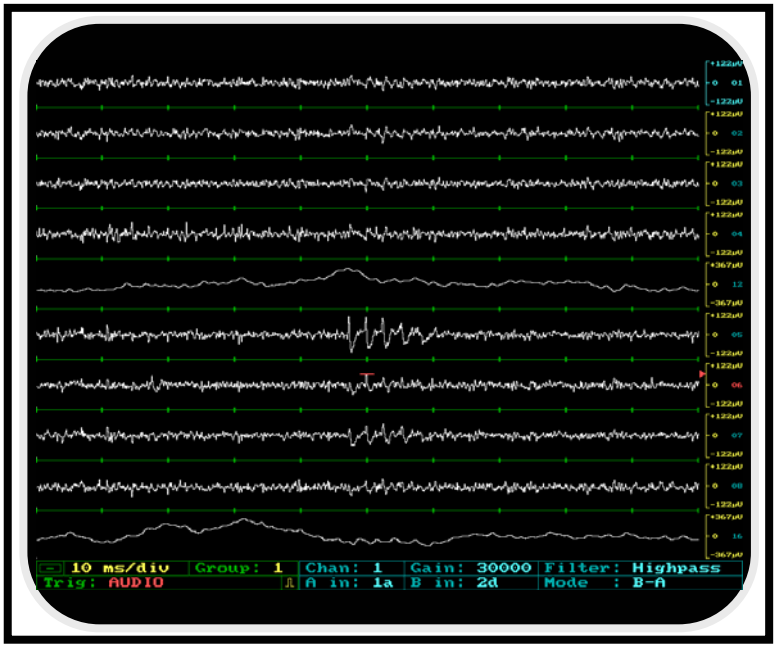
DacqUSB digital oscilloscope

The DacqUSB recording software contains an integral digital oscilloscope that obviates the need for an external oscilloscope, and so reduces the bulk (and cost) of the total system. The digital oscilloscope provides the interface for user control of settings such as filtering, gain, referencing and triggering.

Features:

- Displays up to 10 channels simultaneously, in 10 horizontal divisions, with sweep rates from 1 ms to 1 sec per division.
- Recording channels can be assigned arbitrarily to oscilloscope channels to facilitate comparison between pairs or groups of signals.
- Eight independent groups of 10 channels may be configured, accessed by a single keystroke or mouse click.
- Referencing, gain and filtering independently adjustable (by mouse or keyboard) for each channel.
- Signal amplitudes displayed in units of microvolts or millivolts according to gain setting.
- Peak-detect or averaging modes for slow sweep rates.
- Oscilloscope can be free-running, triggered (see below) or free-running with transient hold following a trigger (settable delay); The transient-hold feature allows visual assessment of spike activity on individual channels while still monitoring ongoing activity across all channels.
- Triggering either internally (from any of the displayed channels) or externally (e.g. from the audio amplifier, stimulator, or other digital input); positive- or negative-edge triggering.
- Trigger point settable at 10% to 90% of display span.
- Screen dumps for instantaneous signal capture, previous data can also be played back at reduced speed.
- Quadruple-resolution mode (instead of 10 channels, only four are displayed, the first of which is enlarged by a factor of four), to allow visualization of fine signal details, e.g. for field potential recording.



A typical display from the digital oscilloscope showing simultaneous single unit recording on 8 channels (1-4 and 6-9), and EEG recording on 2 channels (5 and 10). The electrode configuration was tetrode, and channels 1-4 are the signals from tetrode 1, with channels 6-9 the signals from tetrode 2.

The sweep rate is 10 ms/div, so that the horizontal extent of the display represents 100 ms.

The amplitude of the signals is shown on the vertical axes. The panel along the bottom shows the data collection parameters. On the left are those applying to all channels: the timebase, trigger type and the “group” (i.e., which set of electrodes is currently displayed). On the right is shown the currently selected channel (channel 1) to which the remaining displayed parameters apply: signal and reference electrodes for this channel, gain, filtering and “mode” (whether the signal is referenced, single-ended, inverted or not, etc.). All of these parameters can be changed by either mouse-click or keypress.

DacqUSB recording modes

Data collection in DacqUSB occurs in either of two modes:

- Single unit (optimized for collecting neuronal spikes).
- Raw data.

Single unit mode - Data are collected from channels in groups of 4 (each group a presumed tetrode), 2 (stereotrodes), or 1 (single electrodes). When the signal on any of the channels in an active group exceeds a user-determined threshold, the signal on all of the channels in the group is collected for the 200 μs preceding and 800 μs following the trigger event. Single-unit collection can be integrated with positional data from the video tracker, and digital inputs from experimental apparatus-derived signals.

- Optional artefact rejection, based on a simple spike waveform template.
- Displays spikes or position data during collection, as well as up to two EEG (or other low-frequency analogue) signals.
- Unit data is sampled at 48 kHz, EEG at 1 kHz.
- Recording may be started or stopped by digital input signals.

Raw mode - Data not separated into spikes, but rather all collected samples are dumped to disk for off-line analysis.

- Data sampled at 24 or 48 kHz, up to 24 bits per sample.
- Translation routines provided to allow data conversion into a text format suitable for import into almost any other package.
- Matlab import functions allow data to be loaded into Matlab for analysis.

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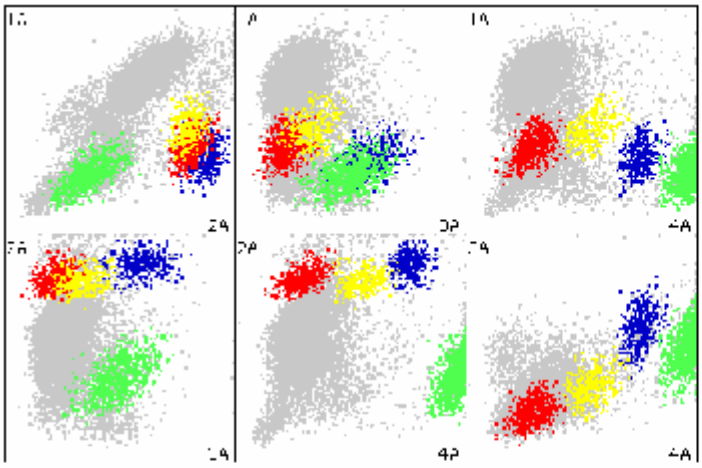
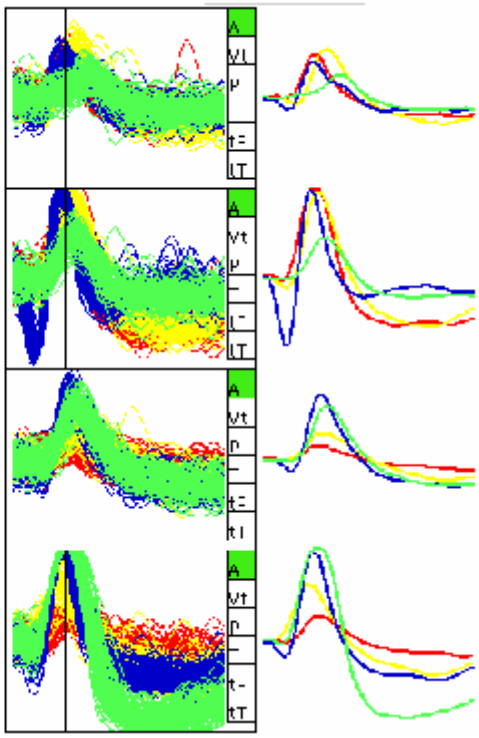
DacqUSB data analysis

The currently-supplied analysis software (Tint) is a tetrode-based cluster-cutting program that runs under UNIX and Windows. It was designed for the analysis of hippocampal place cell activity. In addition to this we provide a Windows-only package which allows firing rate correlation with various behavioural measures, and easy integration of custom-designed software to suit individual experimental protocols.

The spikes collected by DacqUSB are characterised by a set of parameters including peak-to-peak amplitude, onset latency and amplitude at a user-specified time. Electrode-pair scatterplots are generated and separated into clusters either by a hand-drawn polygon or by a k-means clustering algorithm. Position points (obtained from the output of the video tracker), are smoothed and plotted. Head direction can be calculated if two headlights of known orientation were tracked.

After the spikes have been separated, the location at which they occurred can be superimposed on the position plot and the result smoothed and contour-plotted to allow calculation of the location and rate of the field's peak.





Above: the scatterplots generated by pairwise comparisons of the 4 electrodes of a tetrode. Clusters within the scatterplot were identified and isolated using Tint. Right: A representative 100 waveforms from each of the separated clusters, showing the signature waveform for each of the cells.

Additional features and options

Test signal generation

The preamplifier unit contains a test signal generator which allows the system to self-test any aspect of its functionality from the headstage connector all the way through to the PC. In order to extend this to check the functioning of headstages and cables as well, a separate test signal source is available. The test signal generator (known to us as the "test rat") produces two low-amplitude (200 μV) sine-wave signals, at 1 kHz and 6 kHz respectively. This allows headstage buffer amplifiers to be tested for correct functioning and intact wiring. The dual inputs are useful for testing and debugging differential recording setups, where it is necessary to be able to distinguish between the signals arriving at the A and B inputs of the differential amplifier.

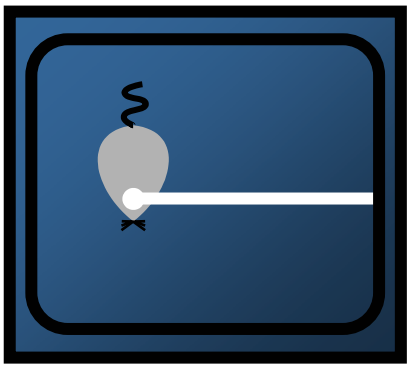
Audio spike monitoring

DacqUSB recording software isolates spikes and presents them back to the experimenter, stripped of ambient noise, via the PC loudspeaker. This is useful in screening for single units, since the ear is better than the eye at detecting cell activity. The output may also be continuous rather than threshold-triggered, and broken into spike-length packets.

Digital I/O module

The digital input/output module provides 16 opto-isolated inputs and 16 opto-isolated outputs, operating at TTL levels. The board also has a dedicated DSP chip which is able to generate precisely-timed pulse patterns which may be used to drive an external stimulus isolator, or experimental apparatus (see "Programmable stimulator"). The pulse outputs from this component are in addition to the 16 opto-isolated outputs. Furthermore, this board can be supplied with a small RF receiver module which allows the operator to control the recording system using a wireless keyring transmitter.

Directional video tracker



The video tracker enables tracking of subjects in an experimental arena, via a head-mounted LED or by subject-background contrast detection (e.g., black rat in white arena).

- Operates in two distinct modes, big/small (for two, differentiated lights) and single-spot (position only).
- Available either stand-alone or integrated within the DacqUSB DSP unit.
- Compatible with both PAL and NTSC camera signals (auto-detected).

The tracker contains a dedicated image processor which allows parameters such as brightness, contrast, tracking “window” etc., to be controlled from the PC. Different setups can be stored to and loaded from disk on a trial-by-trial basis, allowing easy reconfiguration for different arrangements of experimental apparatus or lighting.

The tracker computes the centroid of each light/spot to obtain its x-y coordinate, which is uploaded in real time via the DacqUSB DSP unit (or through a PC USB port if the tracker is operating stand-alone). A composite video output signal allows the tracker configuration (window size, brightness, contrast, etc.) to be displayed on a monochrome or colour monitor; marker lines indicate the position of tracked lights/spots.

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Programmable stimulator

The digital I/O board contains a dedicated DSP chip which forms the basis for a programmable stimulator in conjunction with an external stimulus isolator. Like the tracker, it is available either stand-alone, or as a card that plugs into the DacqUSB DSP unit. It can produce either single pulses or complex, patterned stimuli (such as repeated bursts of tetanization).

Features:

- Standard TTL-level (5 V) output usable with most stimulus isolators.
- Unipolar or bipolar stimulation supported.
- Can be used to trigger the DacqUSB digital oscilloscope for monitoring evoked potentials.
- Stimulus pulse times may be recorded synchronously with single units and slow wave signals.
- A pattern can contain up to 4 levels of periodicity (groups, bursts, trains, and individual pulses).

Above: a stimulation pattern with 3 levels of periodicity (3 bursts of 3 trains of 4 pulses). At each level of periodicity, the pattern at that level and “below” can be set to repeat infinitely (for example, continuous pulses at a programmed frequency, or continuous trains of pulses, etc.).

- Patterns can be chained to create any desired protocol (each pattern can be set to run for a fixed interval). Libraries of individual patterns, or protocols consisting of sets of patterns, can be stored to and loaded from disk, allowing easy reconfiguration for different experimental paradigms.
- Stimulation start can be self-timed or externally driven (e.g. manually, or by other DacqUSB digital input signals).

Microdrive (electrode holder)

One of the biggest obstacles to chronic single unit recording is being able to move electrodes into or through the desired brain area while maintaining sufficient stability to allow recording of the same cell over hours or days. Axona microdrives are based around a precision screw, machined to a pitch of 200 μm, which advances the electrodes in 25 μm steps (1/8th turns). A spring tensions the screw and prevents it from moving spontaneously. The microdrives carry between one and 16 electrodes. They are hand-assembled and are reusable.

Features:

- Lightweight (~1.5 g).
- Custom-built connectors made from long Lemo pins allow easy connection and disconnection, combined with electro-mechanical stability.
- Compression spring maintains tension on the screw and prevents slippage.
- Robust, stainless-steel construction.

Headstage amplifier

This module is a miniature, unity gain buffer amplifier circuit with AC-coupled inputs which is located directly at the subject, and isolates it from the cable connecting it to the recording system. It is usually "tethered" or connected to the recording system preamplifier by means of very low noise hearing-aid wire. The tether cable is typically cut to lengths of 3 m or less to minimise noise-pickup ahead of the preamplifier, but different lengths can be supplied.

Features:

- Available in a variety of sizes and formats, and with numbers of channels ranging from 4 to 32 per module (photo shows an 8-channel device).
- Further miniaturisation is a constant design activity at Axona as new electronic technologies permit.

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