If you want even more in-depth information, be sure to download the Axon guide at moleculardevices.com/axon-guide.

**The Patch-Clamp Rig**

1. **AMPLIFIER(S)**
   
   **What is it?** An instrument that contains the circuitry required to measure electrical currents passing through ion channels or changes in cell membrane potential.
   
   **Why use it?** To measure changes in current or voltage.
   
   The amplifier contains the circuitry necessary to measure current passing through the cell membrane both in magnitude and direction. The amplifier can also measure the cell membrane potential in response to the movement of current. To initiate current movement, the experimenter can deliver a voltage command to the cell, and the cell will respond by passing the current necessary to maintain that voltage command. Conversely, the experimenter may also inject current and then measure the change in membrane potential resulting from that change in current. Choosing where to amplify and filter the signal of interest has implications on signal fidelity. The ideal place to amplify the signal is inside the recording instrument. All models of Axon™ amplifiers use this strategy with variable gain control on the output to provide low-noise amplification of the pipette current or membrane potential. Ploacing the amplification inside the recording instrument minimizes the amount of circuitry between the low-level signal and amplifying circuitry reducing extraneous noise sources.

   Available amplifiers: Axopatch 200B, MultiClamp 700B, Axoclamp 900A

2. **DIGITIZER(S)**
   
   **What is it?** A data acquisition instrument that converts analog signals into digital signals.
   
   **Why use it?** To capture data for analysis.
   
   The current acquired by the amplifier is an analog signal, but in order to perform data analysis needed for high resolution patch-clamp measurements, the analog signal must be converted into a digital one. Positioned between the amplifier and the computer, the digitizer accomplishes this important task. The signal quality the computer receives is extraordinarily important, and this is determined by the sampling frequency, or sampling rate. Actual sampling frequency is user-definable, but in general the Nyquist Sampling Theorem states that at a bare minimum, the sampling rate should be twice the signal bandwidth. However, higher sampling rates are normally used in practice in order to maximize data fidelity with a rate of five or more times the bandwidth frequency often chosen. The latest generation of Digidata® digitizers has the capability of sampling at 500 kHz and is equipped with the HumSilencer feature, which can eliminate 50/60 Hz line-frequency noise. The chosen sampling rate may vary by application requirement, but a frequency should be chosen that optimizes balance between recording fidelity and data storage requirements.

   Available digitizers: Digidata 1550B Low Noise Data Acquisition System plus HumSilencer

3. **SOFTWARE**
   
   **What is it?** Your interface with the amplifier, digitizer, and any other patch-clamp electronics.
   
   **Why use it?** To perform data acquisition and data analysis, as well as to control the digitizer and amplifier.
   
   While the amplifier and digitizer together hold the key circuitry that implements a patch-clamp experiment, the software controls these instruments so they deliver the desired potential(s) and measure the resulting current or voltage. In addition, the software processes the acquired signal with user-defined settings, which can include filtering, normalization, noise removal, curve fitting, and parameter determination.

   Available software: pCLAMP® 10 Software

4. **HEADSTAGE**
   
   **What is it?** A device that holds the micropipettes with built-in circuitry to transmit electrical signals from the micropipettes onto the amplifier.
   
   **Why use it?** The electrical signal acquired by the micropipette needs to be transmitted to amplifier systems for signal processing.
   
   Each headstage is specifically tuned for the amplifier. All headstages contain critical electric circuitry that reduce noise. The headstage is also mechanically controlled by the micromanipulator.

   Available headstages: Axon headstages

5. **MICROSCOPE WITH MICROMANIPULATORS**
   
   **What is it?** The microscope is an optical magnification tool. The micromanipulator is a device that mechanically manipulates the micropipette with nanometer precision, typically allowing 3-dimensional movements.
   
   **Why use it?** To precisely and stably position the micropipette to the area of cell membrane, which is critical for successful recording.
   
   Accurately placing a patch electrode onto a 10-20 µm cell requires an optical system that can magnify up to 300- or 400-fold with contrast enhancement (e.g. Nomarski/DIC, Phase, or Hoffman) and a micromanipulator that stably positions the electrode in 3D space. An inverted microscope is preferable because it allows easier access for electrodes from above the preparation and also provides a larger, more solid platform to both the micromanipulator. A micromanipulator has the ability to move the electrode in very minute distances along the X, Y, and Z axes. The micromanipulator can then hold that position indefinitely.

6. **FARADAY CAGE AND AIR/ANTI-VIBRATION TABLE**
   
   **What is it?** A table and cage around your patch-clamp setup to isolate sources of interference.
   
   **Why use it?** To shield your setup from external interference.
   
   Electrical currents measured during patch-clamp experiments can be extremely small (in the pico-amp range), and any small sources of interference, such as radio waves, can disturb or obscure these signals. A Faraday cage is a wire mesh enclosure around your microscope and recording chamber; it is useful in preventing the electrodes from picking up extraneous noise sources. Additionally, small sources of vibration on the order of pico-meter magnitude can disrupt your recording. Hence, all components must be perfectly positioned throughout the time-course of your experiment, and the air or anti-vibration tables are used to isolate your setup from external sources of vibration that may disrupt this alignment.
The Axon™ Digidata® 1550B Low Noise Data Acquisition System plus HumSilencer™ Adaptive Noise Cancellation is the next generation of low noise digitizers from Molecular Devices (patent pending). It offers the same high-resolution, low-noise signal digitization capabilities as the Axon™ Digidata 1550 and 1550A digitizers, with the added benefit of single-click elimination of 50/60 Hz line-frequency noise up to four channels. Intended for precision scientific applications, it is particularly designed for electrophysiology experiments, to send and receive signals from microelectrode amplifiers, and to interact with peripheral instruments such as solution exchangers.

**KEY FEATURES**

- Built-in HumSilencer in up to four channels enabled by a single click
- Eliminates 50/60 Hz line-frequency noise in less than one second
- Learns noise between sweeps for episodic experiments
- Supports analysis of very small signals
- Eight analog outputs

**Built-in HumSilencer**

The HumSilencer feature’s built-in, software-controlled technology learns and removes local line-frequency noise patterns and associated high-frequency harmonics from incoming signals in less than one second. With a single click, line-frequency noise is subtracted from the incoming signal during data acquisition. The HumSilencer feature provides a fast adaptive rate (within 1 s) for changing noise patterns, digitizes a large range of input signals from -10 to +10 V, and eliminates noise amplitudes at the digitizer’s analog input of up to 20 V peak-to-peak. The HumSilencer feature is not a filter and has no effect on acquired signals. The HumSilencer also causes no signal distortion such as frequency change, amplitude attenuation, phase shift, or DC voltage change.
The low digitization noise is maintained in this digitizer. Analog input channel crosstalk is prevented by the use of separate analog-to-digital converters (ADCs) for each of the analog input channels. Additionally, the use of the latest manufacturing processes and precision components contribute to an extremely low-noise 16-bit signal.

**Superior features**
The Digidata 1550B comes equipped with up to four analog HumSilencer inputs, thus allowing stimulation and recording of multiple cells at once without line-frequency noise. All of the eight analog input channels can be simultaneously digitized at the highest sampling rate of 500 kHz for maximum throughput. Multiple triggering options are available via hardware and software.

**Easy setup**
Simply load the software and plug into a USB 2.0 port to connect to desktop or laptop computers. Connect the power cord to the wall socket and then to the rear panel AC power input connector. All signal connections are conveniently accessible on the front panel.

**Fast noise learning**

![Figure 1. HumSilencer elimination of 60 Hz line frequency noise on four channels. Recordings made from four model cells attached to a MultiClamp 700B amplifier with 60 Hz line-frequency noise introduced by a noise generator placed next to the model cell. Signals were digitized by a Digidata 1550B plus HumSilencer. Black traces: raw data; red traces: same data with HumSilencer enabled.](image1)

![Figure 2. The HumSilencer quickly learns the noise pattern. Recordings made from a model cell attached to a MultiClamp 700B amplifier with 60 Hz line-frequency noise introduced by a noise generator placed next to the model cell. Signals were digitized by a Digidata 1550B plus HumSilencer. Bottom trace: raw data; top trace: same data with HumSilencer enabled. Vertical green lines indicate the time it takes HumSilencer to learn and eliminate noise (0.78245 s). Even if HumSilencer is only enabled after noise appears, it quickly learns and eliminates the noise once it’s turned on.](image2)
Figure 3. HumSilencer quickly adapts to changing noise conditions. Recordings made from a model cell attached to a MultiClamp 700B amplifier with 60 Hz line-frequency noise introduced by a noise generator placed next to the model cell. Signals were digitized by a Digidata 1550B plus HumSilencer. **Bottom trace:** raw data; **top trace** same data with HumSilencer already enabled. At 1.9 and 3.9 s, the amplitudes of the noise increase. In less than one second (time indicated by two vertical green lines, 0.47880 s and 0.66135 s, respectively), HumSilencer learns, adapts, and eliminates the increased noise.

Figure 4. Single-channel recordings from a membrane patch excised from an HEK293 cell transfected with the α-subunit of an olfactory cyclic nucleotide-gated channel. Membrane was clamped at +60 mV in the presence of 2 μM cGMP.

Figure 5. An evoked excitatory postsynaptic current recording from a corticostriatal neuron in a brain slice preparation. The stimulation electrode was placed in the layer V/VI region of the cortex. Membrane was clamped at -70 mV.

Figure 6. Action potential recordings from a neuron in an isolated dorsal root ganglia of a rat brain. Action potentials were evoked by injecting a current step of 110 μA. The resting membrane potential was at -50 mV.
Ordering information
Axon Digidata 1550B Data Acquisition System plus HumSilencer
Part Number: Digidata 1550B4 (four HumSilencer channels)
Part Number: Digidata 1550B1 (one HumSilencer channel)
Part Number: Digidata 1550B0 (without HumSilencer)*
  • Axon Digidata 1550B Digitizer plus HumSilencer
  • Power cord
  • USB 2.0 cable
  • User Guide (electronic)
  • Quick Start Guide (printed)

* Digidata 1550B1 digitizer replaces the Digidata 1550A and provides the same functionality and specifications.

Technical Specifications

<table>
<thead>
<tr>
<th>Performance Specifications</th>
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</thead>
<tbody>
<tr>
<td><strong>Analog outputs</strong></td>
</tr>
<tr>
<td>8 channels, 8 DACs, ±10 V range, 16-bit resolution, 1 Hz–500 kHz sampling rates</td>
</tr>
<tr>
<td><strong>Analog inputs</strong></td>
</tr>
<tr>
<td>8 channels, 8 ADCs, ±10 V range, 16-bit resolution, 1 Hz–500 kHz sampling rates</td>
</tr>
<tr>
<td><strong>Digital outputs</strong></td>
</tr>
<tr>
<td>8 bits, BNC and DB-25F connections</td>
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<tr>
<td><strong>Digital triggers</strong></td>
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<tr>
<td>Start input, tag input, scope output</td>
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<tr>
<td><strong>Telegraphs</strong></td>
</tr>
<tr>
<td>4 BNC input channels or via internal Windows messaging for supported software</td>
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</tbody>
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<table>
<thead>
<tr>
<th>HumSilencer Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maximum input signal (total of noise + signal)</strong></td>
</tr>
<tr>
<td>±10 V</td>
</tr>
<tr>
<td><strong>Maximum noise amplitude</strong></td>
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<tr>
<td>20 V peak-to-peak (on a 0 V signal)</td>
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<tr>
<td><strong>Noise cancellation</strong></td>
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<tr>
<td>Line-frequency (50 Hz / 60 Hz) and harmonics to 10 kHz</td>
</tr>
<tr>
<td><strong>Cancellation response time</strong></td>
</tr>
<tr>
<td>&lt; 1 second</td>
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</tbody>
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<table>
<thead>
<tr>
<th>General Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dimensions (in.)</strong></td>
</tr>
<tr>
<td>4.3 (H) x 19 (W) x 14.3 (D)</td>
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<tr>
<td><strong>Dimensions (cm)</strong></td>
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<tr>
<td>10.9 (H) x 48.3 (W) x 36.3 (D)</td>
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<tr>
<td><strong>Weight</strong></td>
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<tr>
<td>8.8 lbs. (4.0 kg)</td>
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<tr>
<td><strong>Communications</strong></td>
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<tr>
<td>USB 2.0</td>
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<tr>
<td><strong>Rack use</strong></td>
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<tr>
<td>Standard 19&quot; rack mount (2U) with handles</td>
</tr>
<tr>
<td><strong>Power</strong></td>
</tr>
<tr>
<td>100–240 Vac 50–60 Hz, 50 watts (max.)</td>
</tr>
<tr>
<td><strong>Safety</strong></td>
</tr>
<tr>
<td>CE marking (Conformité Européenne)</td>
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<tr>
<td><strong>Computer</strong></td>
</tr>
<tr>
<td>PC with 2 GHz CPU (or faster), Windows 7 (32-bit or 64-bit), 2 GB RAM (or more), 1024 x 768 display, CD-ROM drive, 3 high-speed built-in USB 2.0 ports</td>
</tr>
<tr>
<td><strong>Software</strong></td>
</tr>
<tr>
<td>Axon AxoScope 11 Software (download)</td>
</tr>
<tr>
<td>Axon pCLAMP 11 Software (optional)</td>
</tr>
</tbody>
</table>

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APPLICATION NOTE

HumSilencer: A smart and simple Axon Digidata 1550 Series feature for eliminating line-frequency noise

Introduction
A major challenge in many electrophysiology laboratories is the elimination of 50 Hz or 60 Hz line-frequency noise and the associated high-frequency harmonics. Also called electrical hum, these interfering signals stem from the alternating current (AC) of the electrical mains and are delivered to the lab via power sockets and outlets.

Contamination with line-frequency noise can completely overwhelm biological signals of interest, making sensitive current or voltage measurements impossible. Therefore, elimination of line-frequency noise is critical. However, typical methods for handling this type of noise can be time-consuming and only partially effective. Experiments need to be temporarily stopped while the researcher embarks on a lengthy troubleshooting process to identify and either eliminate or shield the noise sources. While notch filter or off-line filtering methods can be employed, often times these filter-based methods do not fully remove electrical noise, and in some situations, can actually distort biological signals and impair data accuracy.

To rapidly and effectively eliminate line-frequency noise, Molecular Devices has developed the next generation of digitizers—the Axon® Digidata® 1550 Series Low-Noise Data Acquisition System plus HumSilencer™ Adaptive Noise Cancellation (patent pending). The Digidata 1550 Series plus HumSilencer provides a smart and simple way to eliminate line-frequency noise at 50 Hz or 60 Hz and the associated high-frequency harmonics.

What is the HumSilencer feature?
The HumSilencer feature is an advanced, filter-free, adaptive technology that learns and removes local line-frequency noise patterns and associated high-frequency harmonics from incoming signals in less than one second. With a single click, HumSilencer enables sensitive and accurate electrophysiology data acquisition free from line-frequency noise.

Built into the Digidata 1550 A and B digitizers, the HumSilencer feature is accessed through Axon® pCLAMP™ or Axon™ Axoscope software. Clicking a simple ON/OFF box enables/disables subtraction of line-frequency noise in real time during data acquisition.

If the pattern of the line frequency noise changes, such as by the introduction of a new noise source or through an increase in existing noise, HumSilencer rapidly learns and adapts. The new noise is eliminated in less than one second and can handle amplitudes up to 20V peak-to-peak at digitizer’s analog input.

The HumSilencer feature is not a filter and has no effect on acquired signals. The HumSilencer system also causes no signal distortion such as frequency change, amplitude, amplitude attenuation, phase shift, or DC voltage change.

Benefits
• Eliminates 50/60 Hz line-frequency noise in less than one second
• Built-in HumSilencer enabled by a single click
• Data acquisition with fewer interruptions to eliminate line-frequency noise
• Supports analysis of very small signals
Line-frequency noise elimination by HumSilencer
We validated the HumSilencer noise cancellation performance in a variety of applications. During these tests, whole-cell, excised patch, and extracellular field potential recordings were made using Axon™ Axopatch™ 200B, Axon™ MultiClamp™ 700A, or Axon™ MultiClamp™ 700B amplifiers. The acquired signal was split into two analog input channels of the Digidata 1550A and digitized with analog input channel #0, using the HumSilencer feature. This enables comparison of raw data to data where the HumSilencer feature was used. Acquired and digitized signals were then analyzed using pCLAMP software version 10.5. If no line-frequency noise was observed during the recordings, an external noise generator was placed near the headstage to introduce exogenous line-frequency noise.

As demonstrated in the accompanying figures, the HumSilencer feature eliminates line-frequency noise and the associated high-frequency harmonics in a variety of electrophysiology applications.

Single-channel recordings
Figure 1 demonstrates the power of the Digidata 1550 Series plus HumSilencer in one of the most demanding applications—single-channel recording. Typical currents from single-channel recording are on the order of single to tens of picoamperes (pA). In the presence of ~40 pA of line-frequency noise, the small signal from the single channel is virtually invisible (Figure 1, bottom panel). However, with HumSilencer enabled, the biological signal is revealed (Figure 1, top panel).

Extracellular population spike recordings
The Digidata 1550 Series’s HumSilencer feature works with all types of electrophysiology studies, including extracellular field potential recordings from brain slices (Figure 2). When an exogenous noise source is placed near the headstage during recording of extracellular population spikes (PSs), the shifting baseline prevents accurate measurement of the extracellular PS (Figure 2, bottom panel). When HumSilencer is enabled, the noise
is removed, the baseline flattens, and the extracellular PSs can now be accurately measured (Figure 2, top panel).

**Whole-cell recordings**

We also validated the Digidata 1550 Series plus HumSilencer in whole-cell recordings of spontaneous excitatory postsynaptic currents (sEPSCs). In the bottom panel of Figure 3, naturally occurring line-frequency noise partially obscures the biological signal from whole-cell recordings of sEPSCs from a C. elegans body-wall muscle cell. Only when the HumSilencer feature subtracts out the line-frequency noise does the biological signal become visible and can be accurately measured (Figure 3, top panel).

**Recordings from excised patches**

The last validation shown here is of macroscopic endogenous current recordings of an inside-out excised patch from an HEK cell in response to a voltage step (Figure 4). The bottom panel of Figure 4 shows that evoked macroscopic currents were contaminated with introduced 60 Hz line-frequency noise. In the top panel of Figure 4, the robust, introduced line-frequency noise was effectively eliminated by the HumSilencer system.

**Conclusions**

Here we have demonstrated the power of the Digidata 1550 Series’s HumSilencer feature and validated its effectiveness in four different applications. This is only a small set of applications that benefit from rapid line-frequency noise elimination using HumSilencer. We expect that virtually all electrophysiology studies—whether whole-cell patch-clamp or extracellular recordings—can make use of this feature. By eliminating 50 and 60 Hz noise and the associated high-frequency harmonics, HumSilencer not only prevents the risk of temporary experimental workflow stoppage, it also saves time by eliminating the need to track down noise source(s). With HumSilencer, even very small signals can now be accurately detected, enabling sensitive and accurate data acquisition.

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Axon pCLAMP 11 Software Suite
Flexible data acquisition, smart data analysis

KEY FEATURES
• Program advanced experimental protocols with enhanced Protocol Editor
• Analyze data more accurately with new Population Spike and Action Potential Analyses
• Accelerate your results with the new Automated Event Detection and Batch Data Analysis Macros in the new Clampfit Advanced Analysis Module

The Axon™ pCLAMP™ Software Suite from Molecular Devices is the most widely-used electrophysiology data acquisition and analysis program for control and recording of voltage-clamp, current-clamp, and patch-clamp experiments. The Axon pCLAMP 11 Software Suite consists of Clampex 11 Software for data acquisition, AxoScope 11 Software for background recording, Clampfit 11 Software for data analysis, and now the new optional Clampfit Advanced Analysis Module for a more sophisticated and streamlined analysis.

Clampex 11 Software: flexible electrophysiology data acquisition
The focus of the Axon pCLAMP 11 Software Suite is to provide users with greater flexibility in controlling acquisition of electrophysiology data. The previous Clampex 10 version already has a powerful built-in feature set including flexible Protocol Editor, Membrane Test, P/N leak subtraction, User List and Sequencing Keys, etc. In Clampex 11, we enhance this flexibility even more with a new Protocol Editor featuring an increased number of Epochs and increased sweep duration in Episodic Stimulation acquisition mode. Gap-free mode is greatly improved with the ability to execute episodic-style Epochs and programming of digital and analog outputs. The new Membrane Test in Clampex 11 now allows viewing of multiple channels simultaneously. Independent voltage output at different stage configurations is enabled in each recorded cell. These new features provide Clampex 11 Software unparalleled ease-of-use, which makes it the software-of-choice for controlling experiments.

Episodic and continuous recording modes
Clampex 11 Software is a superior program for stimulating cellular preparations in a sweep-oriented “episodic” mode. Stimulus waveforms can be created from a variety of sources, such as the Protocol Editor in Clampex 11 Software, pCLAMP Software ABF data files, and ASCII text files. The new Protocol Editor (Fig. 1) has been enhanced to allow 50 Epochs in episodic stimulation, and the maximum sweep duration has been extended to 516 seconds at 10 KHz sampling. Gap-free recording (Fig. 2) now features the ability to execute waveforms as well as the ability to program analog
and digital output signals. Standard protocol patterns include steps, ramps, cosines, trains of pulses (biphasic), sinusoidal, or triangular patterns. Waveform stimulation utilizes a variety of timing and triggering aids, including software protocol controls and sequencing, hardware, software, and manual triggering options. Clampex 11 Software supports eight digital output bits during sweeps and eight simultaneous waveforms when used with the Digidata® 1550B digitizer. Advanced “split-clock” capability allows users to shift the sampling rate on a per-Epoch basis during sweeps, such as slowly changing conditioning or recovery phases of cell stimulation. For ease-of-use, all protocol durations are defined in terms of time and sampling rates in terms of frequencies.

Clampex 11 Software supports eight digital output bits during sweeps and eight simultaneous waveforms when used with the Digidata® 1550B digitizer. Advanced “split-clock” capability allows users to shift the sampling rate on a per-Epoch basis during sweeps, such as slowly changing conditioning or recovery phases of cell stimulation. For ease-of-use, all protocol durations are defined in terms of time and sampling rates in terms of frequencies.

Clampex 11 Software can be used to offset voltage level differences between connected instruments, correct liquid junction potential errors arising from ionic solutions, compensate passive leak currents with P/N leak subtraction, or reduce high-frequency noise spikes and slow baseline drift with highpass and lowpass filtering. Clampex 11 Software works to compensate for a wide variety of introduced noise sources. Amplifier gain and filter settings for the Axoclamp™ 900A and MultiClamp™ 700B microelectrode amplifiers are software-telegraphed so microelectrode amplifier settings are stored with the data. With Clampex 11 Software, the latest BNC-telegraphed amplifiers are also supported.

For continuous recording, four different modes are available. Gap-free recording is a simple continuous “chart-recorder” recording mode useful for monitoring single channel events, minis, and other spontaneous activity. New in Clampex 11, users can now execute protocol-editor-style Epochs and program digital or analog outputs in Gap-free recording. Fixed- and Variable-Length Event Detection modes are suitable for recording spontaneous events of regular length or varying length that are separated by long periods of inactivity. The high-speed oscilloscope mode works like a storage oscilloscope to capture triggered fixed-length sweeps of data. By providing all of these recording modes, Clampex 11 Software provides the functionality necessary for a variety of simple and complex experimental protocols.

Cell monitoring

The Membrane Test window (Fig. 3) in Clampex 11 Software allows experimenters to monitor pipette resistance in the bath, formation of high-resistance seals between a cell and a pipette, and to measure cell capacitance \( C_m \), membrane resistance \( R_m \), and access resistance \( R_a \). In Clampex 11, Membrane Test has been greatly enhanced. When using multiple channels, all Membrane Test channels will be displayed on a window simultaneously, allowing experimenters to view the status of each channel in one view. Independent voltage output at different stage configurations is enabled in each recorded cell. These features allow an entire experiment to be recorded in a single file while simultaneously monitoring crucial cell parameters in real time.

Online analysis

To analyze data in real-time, the Clampex 11 Software features online analysis. With online analysis, multiple regions can be simultaneously analyzed by an extensive set of peak-based measurements, such as peak amplitude, area, mean, and standard deviation. Measurement regions can be adjusted in real time for LTP experiments. Several measurements, such as half-width, rise and decay times, and rise and decay slopes, are useful for cardiac analyses. Measurements are displayed in their own windows, and different trace colors are used to identify each search region to simplify interpretation.

Sequencing Keys

Sequencing Keys control the setup and timing of operations, including loading protocols, recording data, setting analog and/or digital holding levels, running the Membrane Test, inserting comments into the Lab Book and data file, and linking to the next operation. By using Sequencing Keys, complex experiments can easily be automated, providing a powerful way to link the actions of an entire experiment.
Clampfit 11 Software: smart data preparation and analysis

The Clampfit 11 Software offers dedicated functions to quickly prepare and analyze data. Noise can be removed from signals using highpass, lowpass, and bandpass filters with Bessel, Butterworth, Chebyshev, Gaussian, or RC responses. Specialized notch and electrical interference filters can be used to remove specific noise frequencies and harmonics from recorded signals. Several different methods are available to adjust the baselines of recordings: constant values or averages can be subtracted from all points of the recording, linear drifting baselines can be adjusted by applying a slope correction, or, for unstable baselines, a manual correction using a poly-line can be applied. Additional data analysis functions are averaging, normalization, control subtraction, and peak alignment.

Data analysis

Included with Clampfit 11 Software is a comprehensive palette of tools for analyzing and graphing electrophysiological data. For curve fitting, users can select from 37 pre-defined functions or define their own. Fits can be customized by selecting fitting methods and applying fitting seeds, models can be compared with different terms, and fits can be extrapolated to view curves, components, residuals, taut, etc. Specialized analysis tools include Fast Fourier Transform, Variance-Mean analysis, Perievent analysis, Burst analysis, and other statistical analyses. To display results and data, a range of graph types are available in the Graph windows. Graphs are dynamically linked to their Results window so any manipulations made in the Results window updates the corresponding data in the Graph window. Numerous peak statistics can be directly measured. In this latest version, experimenters can select 24 separate regions of interest as well as a baseline region, thus enabling the analysis of complex data. Online statistics can be recreated during offline review, eliminating the need to save separate statistics files during acquisition. A power spectrum (FFT) for noise analysis can be applied to individual, averaged, or segmented spectra and produces a log-scaled graph of the results. Standard auto and cross-correlation analyses provide the means to compare data for patterns within or across populations. For synaptic modulation studies, the V-M analysis in Clampfit 11 Software provides a robust method for pre-/post-synaptic site identification.

Event detection analysis

Clampfit 11 Software has extremely flexible event detection that analyzes spontaneous and evoked action potentials and post-synaptic data. Events are detected by either crossing a threshold or through a pattern-matching Template Search. Template Searches are designed for analyzing spontaneous events, such as miniature synaptic EPSPs and IPSPs. These events vary in amplitude but not shape, and thus are ideal for detection by the Clampfit 11 Software scalable shape-based algorithm. For added flexibility, multiple categories of events can be simultaneously detected and sorted for secondary analysis. The integrated environment of Clampfit 11 Software links the detected events in the data to the spreadsheet and graph windows to enable quick evaluation of the information within the context of the entire dataset.

Single-channel analysis

The Clampfit 11 Software single-channel analysis allows full processing of up to 1 million events on continuous and episodic data. Open, closed and sub-conductance states of ion channels in natural or artificial membranes are detected and measured. Up to eight levels of open states are supported.

An adjustment for baseline drift can be automatically applied, and an idealized record of the channel activity created. Amplitude and dwell-time histogram plots, including log and cumulative plots, can be created. Clampfit 11 Software also has specialized analyses, such as P(open), burst analysis, latency analysis, evoked response analysis, and nonstationary fluctuation analysis to estimate channel conductance.

Spreadsheet analysis

Primary analysis results populate a spreadsheet where secondary analyses can be performed. These results can be analyzed within Clampfit 11 Software or exported to Microsoft Excel for further analysis. The secondary analyses available within Clampfit 11 Software are analysis of variance, F-test, Chi-squared, Kolmogorov-Smirnov, rank correlations, and Student’s t-Test. Graphing secondary data can be as easy as selecting a data column and clicking on the Create Graph button. Available graphing options include line, scatter and various histogram plots (e.g., normalized, frequency, log [square root] and cumulative).

Clampfit Advanced Analysis Module

The Clampfit Advanced Analysis Module is a set of tools that expands the capabilities of Clampfit to combine powerful analyses with ease-of-use. Data analysis has traditionally been a bottleneck in the patch-clamp experimentation workflow. The Batch Analysis Macros within the Clampfit Advanced Analysis Module solve this problem by applying automation principals to analyze similar data sets. Additionally, the Clampfit Advanced Analysis Module has specialized algorithms to extend the capabilities of Event Detection. Use the enhanced Automated Event Detection to eliminate the need for cumbersome third-party data analysis packages and go from data acquisition to results quickly and easily, in one simple-to-use software, without data file conversion.

Automated Event Detection

The Clampfit Advanced Analysis module provides an enhancement to the already-sophisticated Automated Event Detection engine built into Clampfit. Simply load your data file in Clampfit and highlight the portion of your data file to search. Automated Event Detection will identify events based on user-defined parameters. Event detection has been enhanced to provide automated detection and measurement of population spikes and paired pulses. During detection, programmatically-determined measurements can be edited by graphically repositioning the peaks and end points of the events. If included in an optionally specified search region, stimulus artifacts are automatically detected and used to determine latency times. Multiple spike responses and paired pulse data are processed with no additional set-up requirements.
Action potential detection and measurement has been considerably enhanced and assigned to a separate detection option which allows for the selective measurement of all action potential properties such as rise and decay times, threshold potentials, after-potentials duration and amplitude, and many more.

**Population Spike Analysis**
Population spike recordings (Fig. 4) and paired-pulse experiments, while simple to collect, have traditionally been difficult to analyze. That changes with the Advanced Analysis Module in Clampfit 11. The Population Spike Analysis tool uses interface where the experimenter can choose the direction of the spike and specify the area to be analyzed. This tool will automatically calculate the amplitude, area under the curve, half-width, rise time, decay time, rise slope, decay slope, peak-to-peak frequency, peak-to-peak time, change in amplitude per peak, afterpotential amplitude, afterpotential duration, and threshold potential. The Action Potential Analysis tool can also be used analyze action potential pulse train with the same ease.

**Batch Data Analysis Macros**
The Clampfit Advanced Analysis Module contains a Batch Data Analysis Macro (Fig. 5) that allows experimenters to apply macros to analyze acquired data. Batch analysis saves time by analyzing abundant amounts of data created by the same protocol. Just set up your analysis once and apply it to newly-acquired data. To use batch analysis, simply turn on the macro capture feature, analyze your data, and save the macro. When you have additional data to analyze which have been collected with the same protocol, simply apply the saved macro and your data is analyzed automatically.

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*Supports all previous versions in a model line.

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**Types of pCLAMP licenses available**

<table>
<thead>
<tr>
<th></th>
<th>New features or enhancements</th>
<th>pCLAMP 11 Standard License</th>
<th>pCLAMP 11 Advanced License</th>
<th>Clampfit 11 Advanced Analysis Module License</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clampex 11 Software</td>
<td>• Enhanced Protocol Editor</td>
<td>Included</td>
<td>Included</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>• New Membrane Test</td>
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</tr>
<tr>
<td></td>
<td>• Improved Gap-free recording</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clampfit 11 Software</td>
<td>• 1.5X increase in cursor pairs</td>
<td>Included</td>
<td>Included</td>
<td>—</td>
</tr>
<tr>
<td>Clampfit Advanced Analysis Module</td>
<td>• New Batch Data Analysis Macros</td>
<td>—</td>
<td>Included</td>
<td>Included</td>
</tr>
<tr>
<td></td>
<td>• New Population Spike Analysis</td>
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<tr>
<td></td>
<td>• New Action Potential Analysis</td>
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</tr>
<tr>
<td></td>
<td>• Improved Automated Event Detection</td>
<td></td>
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</tr>
</tbody>
</table>

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The Axon® Axopatch® 200B is the latest version of our premier patch-clamp amplifier incorporating innovative capacitor-feedback technology that provides the lowest-noise single-channel recording available. We have improved the integrating patch clamp amplifier with our proprietary technology, which includes cooling of the active elements in the amplifier to achieve the lowest possible electrical noise. No other amplifier offers such low noise. Positioning an electrode will also be easier with our, slim headstage design that improves access to the preparation.

Other enhancements include three recording configurations in a single headstage (one patch and two whole cell ranges, with capacitance compensation ranges of 100 pF and 1000 pF), increased voltage and current command ranges for electrochemical measurements, built-in capacitance dithering capability for capacitance measurements, and addition of series resistance compensation to the current clamp circuitry to improve performance. The Seal Test now provides current steps in current clamp mode as well as voltage steps in voltage clamp mode. Leak Subtraction is now more sensitive in the most important resistance range. The, slim headstage design improves electrode access to the preparation, and the recording bandwidth has been doubled to up to 100 kHz.

The amazingly low open-circuit noise of 0.13 pA rms (10 kHz) increases to only 0.145 pA RMS when a patch-pipette holder is attached to the headstage input and the pipette capacitance is fully compensated (to eliminate capacitance charging transients). The power of capacitor-feedback technology is shown in Figure 1— capacitor feedback is clearly superior to resistive feedback; cooled capacitor-feedback technology is even better!

Like its predecessors, the Axopatch 200B Amplifier incorporates capacitive and resistive feedback elements in its headstage, providing the best possible performance for single-channel and whole-cell patch clamping. Convenient features include: ZAP (to rupture patches when going whole cell), dual-speed current clamp (to allow faster current clamping in small cells), Holding Command to set voltage commands in voltage clamp mode and current commands in current clamp mode, and a choice of three gain settings on the dedicated current output (for patch, whole-cell and loose-patch modes).
bath is grounded for convenience of use and straightforward addition of command and compensation potentials.

Integrating headstage mode for quiet single-channel recording
With its unprecedented low noise, the capacitor-feedback integrating headstage for the Axopatch 200B Amplifier is ideal for measuring sub-picoamp current signals. The capacitor-feedback circuitry measures current as the rate of voltage increase across the capacitor; the voltage across the capacitor is the integral of the current. In contrast, resistor-feedback circuitry measures current as a voltage drop across a feedback resistor. This has the drawback of requiring extremely high-value resistors that become less ideal as they become larger in value, with accompanying increases in their inherent noise. Noiseless capacitors, on the other hand, are easily manufactured. Thus, capacitor-feedback technology offers the lowest possible noise for single-channel recording.

Through the use of this technology, the electronic circuit noise has been reduced to such a level that the noise inherent in the components themselves has become significant. The Axopatch 200B Amplifier actively cools the critical circuit components to about -15°C in order to reduce the thermal noise and so lowers the noise contribution of the amplifier itself to the lowest levels possible. The Axopatch 200B Amplifier is the ultimate low-noise amplifier.

Unparalleled performance, utility, and ease of use
Included: Efficient controls for whole-cell capacitance compensation, a unique “super-charging” form of series-resistance compensation that complements the conventional “correction” form, and a variable LAG control; output gain with 1000-fold dynamic range; 4-pole lowpass Bessel filter; built-in leak subtraction; dual external-command inputs; versatile panel meter displaying Holding Command, rms current noise, membrane potential, tracking potential, current at the headstage input, and cooled circuitry temperature; telegraphic output of values for output gain, filter frequency, headstage mode (gain) and measured cell capacitance; ZAP; and dual-speed current clamp. Also, the

The introduction of capacitor-feedback technology significantly reduced amplifier noise (Upper trace: resistive feedback; middle trace: capacitor feedback). With active cooling, the Axopatch 200B Amplifier dramatically reduces noise to the lowest levels ever, over the entire bandwidth range (Bottom trace: Axopatch 200B Amplifier).

The actively cooled CV 203BU capacitor feedback headstage used for the Axopatch 200B Microelectrode Amplifier provides ultra-low noise performance in a slim package.

Noise spectra of patch-clamp amplifiers

Axopatch 200B Headstage with Active Cooling
In the design of the integrating patch clamp we addressed two additional technological challenges that are encountered in the pursuit of ultra-low noise. First and foremost, the voltage across the capacitor cannot ramp forever in one direction. Eventually, the supply limits are reached and the electronics must reset to the starting point to continue ramping. During this reset, the system freezes the output at the last measured value. For the best performance, this reset must be kept brief and must occur as infrequently as possible. The reset time of the Axopatch 200B Amplifier is so short (50 µs) that users may never see a reset under most normal recording conditions. Second, to minimize the frequency of resets, the voltage range across the capacitor must be as large as possible. By using unique compensation circuitry, the Axopatch 200B Amplifier manages to use the entire ±10 V range of the power supply to charge the capacitor. This reduces the frequency of resets without incurring the penalty of longer reset times.

**Bilayers**

Headstages useful in artificial bilayer experiments must be stable with large input-capacitance loads. The Axopatch 200B Amplifier is rock solid with an input capacitance of 1000 pF. Furthermore, the integrating technology in the Axopatch 200B Amplifier enables the bilayer voltage to be stepped very quickly. There are two reasons for this. First, the integrator has an inherently large dynamic range that allows it to transiently pass currents of several microamperes. Second, during large command voltage steps the integrator enters the reset state. In this state, the headstage continues to operate as a voltage-clamp amplifier but with a very low feedback resistance. For the few milliseconds that the integrator is in the reset state it can pass up to 1 mA to rapidly charge the bilayer capacitance.

**Resistive headstage mode for superb whole-cell performance**

In whole-cell recording, more current noise is produced by the cell and the environment than by the patch clamp amplifier. Hence, the benefits of a low-noise capacitor-feedback headstage cannot be effectively utilized in whole-cell mode. For this reason, the Axopatch 200B Amplifier uses traditional resistor feedback headstage electronics.
for the whole-cell mode of patch clamp recording. The CV 203BU Headstage includes two feedback resistors to provide a wide range of current-passing capacity in the whole-cell mode. The 500 MΩ feedback resistor \( (\beta = 1) \) provides both low noise and a large current passing ability (20 nA). For larger currents, one can switch to the 50 MΩ feedback-resistor \( (\beta = 0.1) \) to pass up to 200 nA.

**Series resistance prediction**

There are two goals of series resistance compensation. The first is to step the membrane potential to an assigned value as rapidly as possible. One way to speed up this process is to transiently increase the size of the command voltage step (applying a method known as "supercharging"). This causes the charging curve to briefly assume the steeper rate appropriate for a larger step. This transient, high-charging rate is terminated when the membrane potential approaches the intended value. On the Axopatch 200B Amplifier, supercharging is available through the Series Resistance Prediction control. The supercharging transient is automatically and conveniently determined by the user when the conventional whole-cell capacitance controls are set. Prediction refers to our unique algorithm for calculating the added supercharging waveform. Note that this technique does not require the command to be a voltage step; other commands, such as a sine wave, will also be supercharged.

**Series resistance correction**

The second goal of series resistance compensation is to measure the ionic currents. To eliminate error due to the voltage drop across the electrode and to improve the bandwidth of the recording, conventional Series Resistance Correction is required. This technique employs positive feedback to increase the command potential by adding a signal proportional to the measured current to the command input of the headstage.

Series Resistance Prediction and Correction may be used together or separately on the Axopatch 200B Amplifier. The controls are concentric and can be manipulated at the same time. Turning the controls together is quite similar to the series resistance percentage compensation found on other patch clamps. In experiments with real cells, we have found that both the Series Resistance Prediction and Correction on the Axopatch 200B Amplifier can be routinely set to levels exceeding 90%, enabling fast and accurate whole-cell voltage clamping. A variable LAG control permits an even greater degree of series resistance compensation to be achieved, although not at the highest frequencies.
Dual-speed current clamp
The Axopatch 200B Amplifier employs a dual-speed current clamp to optimize speed and stability. The choice of speeds depends on pipette resistance. For pipette resistances above 10 MΩ, the I-Clamp Fast mode can be employed to obtain a rise time of 10 µs under many experimental conditions. The I-Clamp Normal mode guarantees stability for any pipette resistance above 1 MΩ. In addition, current clamp to zero current (I=0 mode) is available, as is a slower clamp to zero current (Track mode) useful for following slow changes in pipette offset while approaching a cell before seal formation. The Holding Command can be used to set a holding current in I-Clamp. Two external command inputs are provided to permit multiple command sources (for cell capacitance experiments, current clamp, etc.). In addition, the Axopatch 200B Amplifier includes series resistance compensation in current clamp mode that allows for correction (similar to the Bridge Balance control of other amplifiers) of voltage errors due to the pipette resistance.

Pipette offset
Researchers are putting ever more unusual solutions into patch pipettes, producing large offset potentials. The Axopatch 200B Amplifier provides ±250 mV offset potential to handle even the most adverse situations.

Dual command potentials
Two separate command potential inputs allow you to sum command input signals from two different sources. For instance, you may wish to constantly supply a low-level sine wave command for evaluation of membrane capacitance. Large voltage steps may be mixed with this signal to construct a C_m versus V_m relationship. One of these command potentials may be switched on from the front panel to access the external source. The other is switched separately on the back panel. The back panel command is scaled to afford greater range (up to ±1 V), and so is quite useful for electrochemical measurements.

Seal test
A convenient Seal Test is built into the External Command potential front panel switch. The oscillator frequency is set to the line frequency for automatic synchronous triggering on any oscilloscope. Seal Test may be used in voltage clamp mode (5 mV pulse) or in current clamp mode (50 pA (β = 1) or 500 pA (β = 0.1)) pulses.

Holding command
The Holding Potential potentiometer can be used to manually establish the cell holding potential for voltage clamp or a holding current for current clamp. The Holding Command of the Axopatch 200B Amplifier has been enhanced over that of its predecessors with the addition of a x1 and x5 switch that allows you to choose either 0±200 mV or 0±1 V ranges. (In current clamp, the command response at β = 1 is 0±2 nA or 0±10 nA, and at β = 0.1 it is 0±20 nA or 0±100 nA.) An ON/OFF switch can disable this control when an external command from a computer is used to establish the holding potential.

Pipette capacitance compensation
Pipette Capacitance Compensation is in operation in both voltage- or current-clamp modes. There are controls to establish the Magnitude and τ of two time constants, Fast and Slow, allowing complete compensation of the pipette capacitance waveform. Magnitude and τ are controlled by concentric knobs allowing easy and convenient adjustment of parameters for each time constant.

Capacitance dithering
Useful for cell membrane capacitance measurement experiments, Capacitance Dithering may be enabled during a TTL-High level signal to Whole Cell Capacitance Dither input to effectively increase the observed cell capacitance by 100 pF (β = 1) or 1 pF (β = 0.1). It may be used in conjunction with the DR-1 Resistance Dither unit (supplied with the Axopatch 200B Amplifier) which normally provides a short-circuit link between preparation and ground. The DR-1 unit inserts a 500 kΩ resistor in series with bath ground during a TTL-High signal and is suitable for finding the phase tracking angle in capacitance measurement experiments.

Output gain
Ten gain settings spanning a 1000-fold range may be selected to scale the output to the most desirable level. Axopatch 200B output swing is ±10 V, providing the greatest compatibility to the vast range of recording devices. However, the dynamic range of the instrument at unity gain is greater than the output swing. Thus a gain value of 0.5 is available to take advantage of the full dynamic range of Axopatch 200B headstage. (Note: The full range is also faithfully reported by the front panel meter.)

Low-pass filters
The scaled output passes through a 4-pole Bessel filter. The five settings from 1 kHz up to 100 kHz allow you to set the lowpass filter appropriate to your application over a range double that previously available.

Panel meter
The panel meter can report values for current and voltage while in any operational mode. Steady-state current is reported to monitor voltage-clamp output. To evaluate noise, current is displayed as an rms value. The V_ms setting is used under current clamp to evaluate membrane potential. In I=0 mode, V_m is the resting membrane potential of the cell. V_HOLD/I_HOLD reports the setting of the Holding Command. The value is reported even when this command...
Specifications

is switched off, allowing you to precisely set a desired holding command in advance. The temperature of the cooled headstage circuitry may be displayed when TEMP is selected.

Leak subtraction
It is often convenient to subtract leak errors during an experiment. The Axopatch 200B Amplifier allows you to correct leak errors as they appear without adjusting your data-acquisition software settings. This is also useful when a large seal leakage is expected, as in loose-patch experiments. Leak Subtraction has been improved in the Axopatch 200B Amplifier by increasing sensitivity in the resistance range most likely to be encountered by researchers.

Zap
To go whole cell it is necessary to rupture the cell-attached patch. As an alternative to carefully controlled suction, the Axopatch 200B Amplifier allows the patch to be ruptured by applying a single +1.3 V pulse for a chosen duration.

Slim headstage design
The re-engineered headstage has only one third the cross-sectional area of other headstages, thereby greatly improving ease of access to the preparation.

Excellent manual
Written by scientific consultants, with the assistance of Molecular Devices staff, the Axopatch 200B Amplifier manual will serve as a useful guide to the operation of the Axopatch 200B Amplifier as well as an informative reference for many aspects of patch clamping.

Pipette holders
The HL-U pipette holder is custom constructed to ensure low-noise mechanically stable recording. Two different barrel lengths are provided. The HL-U holder accepts pipettes of 1.0–1.7 mm OD. It includes a silver wire assembly, and has a 1.0 mm OD post for suction. The Axopatch 200B Amplifier is shipped with one pipette holder.

Technical Specifications

### CV 203BU Headstage

**Construction:** All critical components are in a sealed hybrid and cooled with a solid state cooling element.

**Configuration:** High-speed, low-noise current-to-voltage converter

**Cooling:** Input circuitry -15°C typical. Headstage cooling should be kept on at all times to ensure proper calibration of offset voltages.

**Gain (β):** 1 mV/pA (β = 1) Patch or Whole-Cell modes

1 mV/pA (β = 0.1) Whole-Cell mode

**Feedback element:**

<table>
<thead>
<tr>
<th>Patch</th>
<th>1 pF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Cell</td>
<td>β = 1, 500 MΩ in parallel with 1 pF</td>
</tr>
<tr>
<td>Whole Cell</td>
<td>β = 0.1, 50 MΩ in parallel with 1 pF</td>
</tr>
</tbody>
</table>

**Tuning (Whole Cell mode only):** Tuning circuit to idealize response of the feedback resistor is contained in the main instrument. Tuning is automatically bypassed when the capacitive feedback is selected.

**Pipette-capacitance-compensation injection capacitor:** 1 pF

**Whole-cell-capacitance-compensation injection capacitor:**

<table>
<thead>
<tr>
<th>Patch</th>
<th>none</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Cell</td>
<td>β = 1, 5 pF</td>
</tr>
<tr>
<td>Whole Cell</td>
<td>β = 0.1, 50 pF</td>
</tr>
</tbody>
</table>

**Case:** Connected to ground. Case jack mates to 2 mm plugs.

**Bandwidth:** Test signal applied via Speed Test input

<table>
<thead>
<tr>
<th>Internal</th>
<th>140 kHz patch mode</th>
<th>70 kHz whole-cell mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. external</td>
<td>100 kHz (limited to output filter)</td>
<td></td>
</tr>
</tbody>
</table>

**Capacitative load stability:** 1000 pF, 0 Ω in series

**Maximum instrument noise:** Measured with minimal external noise sources (i.e., radiated line-frequency noise, mechanical vibration) 8-pole Bessel filter

<table>
<thead>
<tr>
<th>Max. Instrument Noise: Without Holder</th>
<th>Patch</th>
<th>Whole Cell</th>
<th>Whole Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line Frequency &amp; Harmonics</td>
<td>β = 1</td>
<td>0.005 pA</td>
<td>β = 1</td>
</tr>
<tr>
<td>0.1–100 Hz</td>
<td>0.030 pA</td>
<td>0.50 pA</td>
<td>1.6 pA</td>
</tr>
<tr>
<td>0.1–1 kHz</td>
<td>0.015 pA</td>
<td>0.25 pA</td>
<td>0.75 pA</td>
</tr>
<tr>
<td>0.1–5 kHz</td>
<td>0.060 pA</td>
<td>0.65 pA</td>
<td>1.65 pA</td>
</tr>
<tr>
<td>0.1–10 kHz</td>
<td>0.130 pA</td>
<td>1.10 pA</td>
<td>3.0 pA</td>
</tr>
<tr>
<td>Max. Instrument Noise: With Holder</td>
<td>0.1–10 kHz</td>
<td>0.145 pA</td>
<td>1.10 pA</td>
</tr>
</tbody>
</table>

**Reset Characteristics (Patch mode only)**

Total reset time: 50 µs ±10%

**Time between resets (TBR):**

For DC currents: TBR = 10 / (I_{DC} - I_{BIAS})

where I_{DC} and I_{BIAS} are in pA and TBR is in seconds.

I_{BIAS} is typically 0.3–1.0 pA.

For transient currents: A reset will occur if the headstage must deliver more than 10 pC of charge to the membrane.

**Reset transients in current waveform at Scaled Output (typical):**

<table>
<thead>
<tr>
<th>Current Clamp</th>
<th>100 Hz</th>
<th>±0.25 pA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 kHz</td>
<td>±0.5 pA</td>
<td></td>
</tr>
<tr>
<td>10 kHz</td>
<td>±2 pA</td>
<td></td>
</tr>
</tbody>
</table>

**Current Clamp**

The speed in I=0 mode is the same as in I-Clamp Normal. In addition, Track mode is a slow clamp to zero current. Note that series resistance compensation remains active in current clamp mode, allowing measurement of pipette resistance and (when Rs is compensated) accurate monitoring of cell membrane potential, but the speed setting is still determined by the actual electrode resistance and not only the remaining uncompensated resistance.

The speed of the current clamp depends on the Mode setting (Normal or Fast), the time constant of the cell and the pipette resistance.
Capacitance Dithering
Enabled during a TTL High level signal to Whole Cell Capacitance Dither input.
Effectively increases the observed cell capacitance by 100 fF (β = 1) or 1 pF (β = 0.1). Useful for cell membrane capacitance measurements. May be used in conjunction with the DR-1 Resistance Dither unit.

DR-1 Resistance Dither unit (supplied with the Axopatch 200B Amplifier) normally provides a short-circuit link between preparation and ground. Inserts a 500 kΩ resistor in series with bath ground during TTL High signal. Suitable for finding the phase tracking angle in capacitance measurement experiments.

Mode
V-Clamp: Pipette voltage is clamped.
I-Clamp normal or fast: Pipette current is clamped to command current from Holding Command knob or external input. Normal mode is stable for electrode resistances greater than 10 MΩ. Fast mode is stable for electrode resistances greater than 10 MΩ. Series Resistance control is active.

Track: Slow I-Clamp to zero current used to correct pipette offset.
(I=0): I-Clamp to zero current. Selected mode sets analog voltage on Mode Telegraph Output.

Command Potentials
Seal test: 5 mV (V-Clamp mode), 50 pA (I-Clamp, β = 1) or 500 pA (I-Clamp, β = 0.1) command at line frequency.
External commands: Two separate BNC inputs, one front-switched, one rear-switched

Input impedance: 10 kΩ. Inputs may be automatically adjusted to maintain zero pipette current.

RMS Noise
A 3.5 digit meter displays RMS current noise in pA. Measurement bandwidth is 30 Hz to 5 kHz. Upper -3 dB frequency is set by 4-pole Butterworth filter.

Pipette offset: Manual: ±250 mV. Ten-turn control with uncalibrated dial.
Track, I=0: +200 mV. Nulling potential automatically adjusts to maintain zero pipette current.

Zap
Amplitude: +1.3 Vp-p at pipette for chosen duration.
Duration: 0.5–50 ms or Manual. Triggered by front-panel pushbutton. In Manual position Zap amplitude is maintained as long as pushbutton is depressed.

Inputs
Forced resets: Positive edge triggered. Initiates a reset of the integrator; has no control over the duration of reset.
Blank activate: Causes Scaled Output and I Output to hold their initial value for the duration of the blanking pulse. Does not affect 10 Vm output.

Speed test: Injects current into headstage input through a 1 pF capacitor. Injected current waveform is the derivative of the voltage waveform applied at Speed Test input. For example, a 100 Hz 10 Vp-p triangle wave will inject a 1 nA p-p square wave into the headstage input.

Signal Outputs
Scaled output: Scaled and filtered by output control settings. Sample and hold pedestal compensation. Output is I (pA) when in V-Clamp or Track modes. Output is Vm (mV/pA) when in I-Clamp mode. BNCs on front and rear panels are identical.

Specifications

Mode:

<table>
<thead>
<tr>
<th>Mode</th>
<th>Track</th>
<th>V-Clamp</th>
<th>I=0</th>
<th>I-Clamp Normal</th>
<th>I-Clamp Fast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scaled Output</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Telegraph</td>
<td>Vm</td>
<td>Vm</td>
<td>Vm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

10 V_m: Membrane potential at x10 gain. Junction potentials removed.

Output Controls

Output gain: 10 values from 0.5–500. Affects superimposed analog voltage on Gain Telegraph Output for reading by computer.

Lowpass Bessel filter: 4-pole lowpass Bessel filter with five settings: 1, 2, 5, 10 and 100 kHz. Selected value sets an analog voltage on Frequency Telegraph Output.

Leak Subtraction: Causes a signal proportional to the command to be subtracted from current record. Range: 100 μA to ∞.

Telegraph Outputs

Gain: Takes α and β gain factors into account.

<table>
<thead>
<tr>
<th>Gain Setting</th>
<th>Vm (mV/mV)</th>
<th>Vm (mV/mV)</th>
<th>Vm (mV/mV)</th>
<th>Vm (mV/mV)</th>
<th>Vm (mV/mV)</th>
<th>Vm (mV/mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>20</td>
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<td>100</td>
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<td>50</td>
<td>100</td>
<td>200</td>
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<tr>
<td>20</td>
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<td>20</td>
<td>50</td>
<td>100</td>
<td>200</td>
<td>500</td>
</tr>
<tr>
<td>50</td>
<td>20</td>
<td>50</td>
<td>100</td>
<td>200</td>
<td>500</td>
<td>∞</td>
</tr>
</tbody>
</table>

‡ Applicable for β = 0.1 only. † Applicable for β = 1 only.

Frequency:

<table>
<thead>
<tr>
<th>Filter Setting (kHz)</th>
<th>Telegraph Output (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>10</td>
<td>8</td>
</tr>
</tbody>
</table>

Cell capacitance (Telegraph output):

0 to +10 V, proportional to setting 0–100 pF for β = 0; 0–1000 pF for β = 0.1. when WHOLE CELL CAP switch is in the ON position. 0 to –10 V, when WHOLE CELL CAP switch is in the OFF position.

Data Not Valid: Output goes High during a reset in Patch mode or for the duration of a Blank Activate pulse in either Patch or Whole Cell mode.

Panel Meter

3.5 digit meter displays Track potential (V_TRACK) in mV, membrane potential (V_m) in mV, current noise (I_NOISE) in pA RMS, membrane current (I) in pA or nA, Holding Command (V_HOLD/I_HOLD) in mV or nA or input circuitry temperature in degrees Celsius (TEMP). Meter has autoranging feature for all settings except TEMP.

Grounding

Signal ground is isolated from chassis and power ground. Signal ground is available on rear panel.

Control Inputs

Above 3 V accepted as logic High. Below 2 V accepted as logic Low. Inputs protected to ±15 V.

Model Cells

Patch-1U model cell emulates three experimental conditions:

BATH: 10 MΩ electrode resistor to ground. 4 pF pipette capacitance.

CELL: 10 MΩ electrode resistor connected to a 500 MΩ/33 pF cell. 4 pF pipette capacitance.

PATCH: 10 GΩ resistor to ground. 5 pF pipette capacitance.

MCB-1U model cell emulates a bilayer membrane. 10 kΩ resistor in series with a 100 pF capacitor.

Pipette Holders

HL-U holders mate to threaded Teflon input connector of the CV headstage. Post for suction tubing is 1 mm OD. HL-U holder accepts glass 1.0–1.7 mm OD. Supplied with silver wire. Optional HLR-U right-angle adapter and HLB-U BNC adapter are available.

General Specifications

Dimensions (in.): 3.5 (H) x 19 (W) x 12.5 (D)
Dimensions (cm): 8.9 (H) x 48.3 (W) x 31.7 (D)  
Weight (lbs.): 11.5 (5.1 kg)
Headstage (in.): 0.75 (H) x 0.70 (W) x 4.2 (D)
Headstage (cm): 1.9 (H) x 1.9 (W) x 10.5 (D)
Mounting plate (in.): 2.0 (H) x 2.5 (D)
Mounting plate (cm): 5.1 (H) x 6.4 (W) x 6.2 (D)
Communications: Analog and digital BNC

Ordering information

Axopatch 200B Microelectrode Amplifier
Part Number: AXOPATCH 200B-2

• Axopatch 200B instrument
• (1) CV 203BU headstage
• (1) Headstage mounting plate
• (1) HL-U pipette holder
• (1) Patch-1U model cell
• (1) MCB-1U bilayer model cell
• (1) DR-1 series resistance dither unit
• (1) Spare fuse
• Theory and Operation user guide (printed)

Optional accessories

• Single headstage unit

Contact Us

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Email: info@moldev.com

Check our website for a current listing of worldwide distributors.

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The MultiClamp™ 700B Microelectrode Amplifier from Molecular Devices is a computer-controlled microelectrode current- and voltage-clamp amplifier for electrophysiology and electrochemistry. This versatile amplifier is capable of single-channel and whole-cell voltage patch-clamp, high-speed current-clamp (sharp electrode or field potentials), ion-selective electrode recording, amperometry/voltammetry and bilayer recordings. The MultiClamp 700B amplifier is designed to support up to two primary CV-7B headstages and two optional auxiliary (HS-2 or VG-2 type) headstages. Each CV-7B headstage contains a current-to-voltage converter for voltage-clamp and a voltage follower for true current-clamp. This allows the user to conveniently switch between low-noise patch-clamp recording and high-speed current-clamp recording. An optional CV-7B/BL headstage is available for bilayer recording.

**KEY FEATURES**

- Computer-controlled amplifier capable of single-channel and whole-cell voltage patch-clamp, high-speed current clamp (sharp electrode or field potential), and more
- Support up to two primary headstages and two optional auxiliary headstages

**Powerful features**

The MultiClamp 700B Amplifier uses either an external trigger command or user-programmable voltage threshold for rapid, automatic mode-switching between current and voltage-clamp. For example, by pre-setting a voltage threshold in current-clamp mode, the amplifier will automatically switch to voltage-clamp mode when the membrane potential reaches the threshold voltage. A user-specified delay can be programmed allowing further customization of recording procedures.

Sudden changes in membrane or pipette parameters may result in undesirable oscillations during whole-cell recordings. To overcome this, the MultiClamp 700B amplifier detects current or voltage oscillations and automatically disables or intelligently reduces compensation settings to protect the cell from damage.
The small profile of the CV-7B headstage makes it easy to incorporate into an electrophysiology setup. The dovetail design integrates with a base plate for easy attachment to micromanipulators.

Simplified CV-7B diagram. The CV-7B headstage contains both resistor feedback voltage-following circuitry for true current-clamp operation, and voltage-to-current circuitry for voltage-clamp operation.

Slight voltage drift, often due to changing electrode properties, may contaminate an otherwise decent current-clamp recording. In order to maintain the membrane potential at a consistent level, the MultiClamp 700B amplifier automatically injects a compensatory current over a user-defined time course.

The MultiClamp 700B amplifier enables researchers to perform experiments that were previously not possible using a single amplifier.

**True current-clamp and voltage-clamp headstage**

Traditionally, amplifiers are designed for optimal performance in voltage-clamp or current-clamp mode, but cannot perform both during the same experiment. The CV-7B headstages supplied with the MultiClamp 700B amplifier overcome this limitation by integrating both current-to-voltage and voltage-following circuitry. This design allows users to rapidly switch between patch-clamp recording and high-speed current-clamp recording. The CV-7B headstage has four different feedback resistors in voltage-clamp mode, allowing for a wide range of cellular recording. In current-clamp mode, the CV-7B headstage provides three different current setting resistors to clamp current from a few pA up to 200 nA.

With two headstages, the MultiClamp 700B amplifier can perform the function of two patch-clamp, two current-clamp, or a combination of patch- and current-clamp amplifiers. In addition, two optional voltage-follower headstages (HS-2 type) can be connected to auxiliary inputs to allow third- and fourth-point voltage recording. Dual headstages allow more complex synaptic experiments to be performed, as well as increasing throughput for drug discovery experiments, all at a significantly lower cost per channel.

Specialized headstages are available for bilayer and electrochemistry recordings. The optional CV-7B/BL headstage was designed to handle the large membrane capacitances found in bilayer recording. The CV-7B/EC headstage was designed to handle the large (±2V) command voltages required during electrochemistry recording.

**Computer control**

**MultiClamp 700B Commander Software**

The MultiClamp 700B amplifier is fully controlled by the MultiClamp Commander software. Computer control allows for tremendous flexibility, including broad ranges of current passing and recording levels, extensive filtering options and multiple signal outputs. Computer control simplifies the patching process by providing automation of pipette offset, fast/slow electrode capacitance compensation, whole-cell capacitance compensation, series resistance correction, pipette capacitance neutralization and bridge balance—all without moving parts.

**Third-party programming**

A Software Development Kit (SDK) is included to allow full integration of the MultiClamp Commander Software into third-party applications.
Voltage-clamp functions.

- **Seal Test** with variable amplitude and frequency
- **Fast/Slow electrode capacitance compensation** (automatic/manual) with auto-disable in case of oscillations
- **Whole Cell capacitance compensation** (automatic/manual)
- **Output Gain** scales primary and secondary output

Current-clamp functions.

Note: Some functions are common to both voltage and current-clamp.

### Voltage- and Current-Clamp Functions

**Software user interface features**

Two meters display output voltage (or resistance) and current (or $I_{rms}$) for each channel. An Options menu allows easy set up of filters, headstage feedback resistors, audio signals, mode switching and advanced capacitance compensation parameters. Computer control allow the amplifier configuration to be saved and easily re-opened. The last state of the amplifier is independently maintained during a power-off condition. The MultiClamp Commander Software interface is not dependent upon any particular data acquisition software, and therefore can be used with most data acquisition systems in standalone mode.

**Smart telegraphs**

As the amplifier interface, the MultiClamp Commander Software provides vital information to the data acquisition program about the state of the amplifier. In addition to the values that are typically telegraphed by hardware connections on conventional amplifiers (cell capacitance, filter cutoff frequency, and output gain), the MultiClamp Commander Software provides five additional signal settings: command sensitivity, operating mode (voltage/current-clamp), scaled output signal, scale factors and scaling units of the output signal. These additional settings allow the data acquisition software, such as pCLAMP® 11 Software, to automatically configure stimulus and recording signals based on the commander software settings.

**Comprehensive microelectrode amplifier solution**

The MultiClamp 700B Microelectrode Amplifier offers high-quality voltage- and current-clamp capability with fast mode switching and oscillation suppression, all under convenient computer control. Together with its extensive set of signal conditioning features, the MultiClamp 700B amplifier is the choice for a large variety of experimental needs. Whether you perform whole-cell, excised or cell-attached patch-clamp recordings, sharp-electrode, field potential or ion-selective measurements, bilayer recordings with voltammetry or amperometry, the MultiClamp 700B Amplifier is a comprehensive solution for your microelectrode amplifier applications.

### General specifications

| Dimension (in.) | 3.5 (H) x 19 (W) x 12 (D) |
| Dimension (cm)  | 8.9 (H) x 48.3 (W) x 30.5 (D) |
| Weight (lbs.)   | 10 (4.54 kg) |
| Headstage (in.) | 0.875 (H) x 1.625 (W) x 2.3125 (D) |
| Headstage (cm)  | 2.0 (H) x 4.0 (W) x 8.4 (D) |
| Channels        | 2 (sharing a common ground) |
| Communications  | USB 1 Type B female ports |
| Rack use        | Standard 19” rack-mount (2U) with handles |
| Benchtop use    | Bayonet feet |
| Power           | 85–260 Vac 50–60 Hz, 30 watts (max.) |
| Safety          | CE marking (Conformité Européen) |
| Computer        | 1 GHz or better processor; Windows XP Pro / 2000 / 98 SE or Mac OS X 10.4.6 (Tiger), CD-ROM drive 512 MB RAM, 500 MB HD space, 2 USB 1 ports |
| Software        | MultiClamp™ Commander Software (included) |
## Test signals

**Voltage-clamp**
- Seal test amplitudes: 0 to ±1 V at electrode
- Pulse amplitudes: 0 to ±1 V at electrode
- Seal test frequency: Selectable from 2–1000 Hz
- Pulse duration: Selectable from 01–500 ms
- Zap: Fixed at ±1 V with selectable 0.025–50 ms duration

**Current-clamp**
- Tuning amplitude: 0 to ±10 VR, A at electrode (see DC range)
- Tuning frequency: Selectable from 2–1000 Hz
- Pulse amplitude: 0 to ±10 VR, A at electrode (see DC range)
- Pulse duration: Selectable from 01–500 ms
- Buzz amplitude: Fixed at 15 V signal to the headstage capacitor, with selectable 0.05–500 ms duration
- Clear (+) amplitude: Fixed at ±15 V signal to the headstage capacitor

### DC holding commands

**Voltage-clamp**
- Holding: ±1000 mV
- Pipette offset: ±100 mV

**Current-clamp**
- Range: ±200 nA (50 MΩ R<sub>f</sub>), ±20 nA (500 MΩ R<sub>f</sub>), ±2 nA (5 GΩ R<sub>f</sub>)
- Pipette offset: ±200 pA

### Output gain and filters

**Scaled output filters**
- Lowpass
- Bessel cutoff: 2–30 kHz, Bypass
- Butterworth cutoff: 3–45 kHz, Bypass

**Current-clamp**
- Range: ±200 nA (50 MΩ R<sub>f</sub>), ±20 nA (500 MΩ R<sub>f</sub>), ±2 nA (5 GΩ R<sub>f</sub>)
- Pipette offset: ±200 pA

**Lowpass**
- 1 kHz, 3 kHz, 10 kHz, Bypass (-3 dB)

**Audio monitor**
- Current or voltage (x 1 or x 100) from either Channel 1 or Channel 2 is available for direct monitoring or via a voltage-to-frequency converter (VCO)
- VCO range: 4 kHz at +100 mV to 0.3 kHz at -100 mV
- Audio output: Jacks drive a 50 Ω headphone directly, or a powered external speaker
- Audio input: Jacks allow mixing of amplifier output with other signals, such as a PC sound card output

### Ordering information

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<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Part number</th>
</tr>
</thead>
<tbody>
<tr>
<td>MultiClamp 700B Amplifier</td>
<td>MultiClamp 700B Amplifier with power cord, (2) CV-7B headstages (with mounting plates), (2) Patch-1U model cells, (1) MultiClamp commander software CD, (1) USB cable, Theory and operation user guide (printed)</td>
<td>MULTICLAMP 700B</td>
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<tr>
<td>SoftPanel™ Controller</td>
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<td>Auxiliary headstages</td>
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<td>HS-2 series</td>
</tr>
<tr>
<td>For virtual ground or bath clamp</td>
<td>VG-2 series</td>
<td></td>
</tr>
<tr>
<td>Bilayer model cell</td>
<td>1-MCB-1U</td>
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</tbody>
</table>

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Patch clamp electrophysiology

Electrophysiology is one of the foundational disciplines in neuroscience and cardiac physiology for the evaluation of ion channels. The Patch-clamp technique is a versatile electrophysiological tool for understanding ion channel behavior.

Every cell expresses ion channels, but the most common cells to study with patch-clamp techniques include neurons, muscle fibers, cardiomyocytes, and oocytes overexpressing single ion channels. To evaluate single ion channel conductance, a microelectrode forms a high resistance seal with the cellular membrane, and a patch of cell membrane containing the ion channel of interest is removed. Alternatively, while the microelectrode is sealed to the cell membrane, this small patch can be ruptured giving the electrode electrical access to the whole cell. Voltage is then applied, forming a voltage clamp, and membrane current is measured. Current clamp can also be used to measure changes in membrane voltage called membrane potential. Voltage or current change within cell membranes can be altered by applying compounds to block or open channels. These techniques enable researchers to understand how ion channels behave both in normal and disease states and how different drugs, ions, or other analytes can modify these conditions.

**cSEVC**

What is continuous single-electrode voltage clamp (cSEVC)? It is an electrophysiology patch-clamp method that passes a membrane voltage into a cell and measures the change in current as the voltage steps.

**dSEVC**

In discontinuous single-electrode voltage clamp (dSEVC), the tasks of voltage recording and current passing are allocated to the same micropipette.
**Action Potential**

An action potential is a rapid rise and subsequent fall in voltage or membrane potential across a cellular membrane with a characteristic pattern. Examples of cells that signal via action potentials are neurons and muscle cells.

**Digital Acquisition**

The current or voltage signal acquired by the amplifier is an analog signal, but to perform data analysis needed for high resolution patch-clamp measurements, the analog signal must be converted into a digital one. Positioned between the amplifier and the computer, the digitizer accomplishes this important task. Signal quality is extremely important and is impacted by the sampling frequency. The latest generation of Digidata digitizers sample at 500 kHz and can be equipped with HumSilencer, which eliminates 50/60 Hz line-frequency noise.
Single Channel Recording

The patch-clamp technique involves a glass micropipette forming a tight gigaohm seal with the cell membrane. The micropipette contains a wire bathed in an electrolytic solution to conduct ions. To measure single ion channels, a “patch” of membrane is pulled away from the cell after forming a gigaohm seal. If a single ion channel is within the patch, currents can be measured. The Axopatch 200B, with extremely low-noise profile, is ideal for this application, maximizing signal for the smallest conductance ion channels.

Action Potential Search

Action potentials represent important cellular events. Without action potentials, hearts would not beat, and neurons would not fire, so measuring these events is essential. The Action Potential Search tool in Clampfit 11 Advanced module detects all action potentials in the data file. It applies user defined and programmatically determined metrics including amplitude, AP duration, rise and decay time, rise and decay slope, peak to peak frequency and time, amplitude delta per peak, afterpotential amplitude and duration, and threshold potential.
Ion Channels

An ion channel is a group of proteins that form a pore across the lipid bilayer of a cell. Each channel is permeable to a specific ion (examples: potassium, sodium, calcium, chloride). Patch-clamp is used to evaluate current or voltage in the membrane associated with ion channel activity via direct measurement in real time using ultra-sensitive amplifiers, high-quality data acquisition systems, and powerful software to evaluate the results.

Patch Clamp

The patch-clamp technique involves a glass micropipette forming a tight gigaohm (GΩ) seal with the cell membrane. The micropipette contains a wire bathed in an electrolytic solution to conduct ions. The whole-cell technique involves rupturing a patch of membrane with mild suction to provide low-resistance electrical access, allowing control of transmembrane voltage. Alternatively, investigators can pull a patch of membrane away from the cell and evaluate currents through single channels via the inside-out or outside-out patch-clamp technique.
Whole Cell Recording

The whole cell patch-clamp technique involves a glass micropipette forming a tight gigaohm (GΩ) seal with the cell membrane. This micropipette contains a wire bathed in an electrolytic solution to conduct ions. A patch of membrane is subsequently ruptured by mild suction so that the glass micropipette provides a low-resistance access to the whole cell, thereby allowing the investigator to control the transmembrane voltage and allowing the investigator to evaluate the sum of all currents through membrane-bound ion channels.

Series Resistance Compensation

Series resistance is the sum of all resistances between the amplifier and the inside of the cell using the whole-cell recording method. Due to Ohms Law, the larger this resistance, the greater the difference between the command level and the measured values. This creates an error in actual voltage or current measurement potentially leading to inaccurate observations. To overcome this, the Molecular Devices amplifiers have built-in circuitry to improve the bandwidth of the recording by compensating the error introduced by the voltage or current drop across the series resistance.
In an experiment using the voltage-clamp method, the investigator controls the membrane voltage in a cell and measures the transmembrane current required to maintain that voltage. This voltage control is called a command voltage. To maintain this command voltage level, an amplifier must inject current. The current injected will be equal and opposite the current escaping through open ion channels, allowing the amplifier to measure the amount of current passing through open membrane bound ion channels.

Current-clamp is a method used to measure the resulting membrane potential (voltage) from an injection of current. To measure the membrane potential, the MultiClamp 700B and Axoclamp 900A both monitor voltage drop initiated by current injection along an in-series resistor. Current-clamp is commonly used to inject simulated, but realistic current waveforms into a cell, and monitor membrane effect. This technique is ideal for the evaluation of important cellular events such as action potentials.
50/60 Hz line-frequency noise, also known as electrical hum, is the most common source of background noise in patch-clamp electrophysiology experiments. This noise can overwhelm biological signals of interest, making sensitive patch-clamp measurements nearly impossible. Traditional trouble shooting is typically only partially effective and can impair data accuracy. HumSilencer is a filter-free, adaptive technology that learns and removes line frequency noise without using methods that impair signal accuracy like filters, that can distort biological signals.

Ion channels are involved in many cell pathways and understanding the function of ion channels in response to changes in membrane potential or the presence or absence of other molecules is important in order to understand exactly how ion channels participate in normal and abnormal biological processes such as cell differentiation and migration, disease states, and neuronal communications.
Disease Research

Ion channels play a role in many diseases including hypertension, cardiac arrhythmias, gastrointestinal, immune and neuromuscular disorders, pathological pain, and cancer. By understanding the exact role that ion channel play in a particular disease, researchers might be able to find a way to affect the ion channel in such a way as to alter the course of the disease.

Population Spike Search

Population spike recordings and paired-pulse experiments, while simple to collect, have traditionally been difficult to analyze. That is no longer the case with the Clampfit Advanced Analysis Module in pCLAMP 11 Software. The Population Spike Search tool will automatically locate population spikes based on user defined parameters and calculate the amplitude, area under the curve, half-width, rise time, decay time, rise slope, decay slope, and coastline of population spikes and paired-pulses.
**Batch Data Analysis Macros**

Clampfit Advanced Analysis Module, part of the pCLAMP 11 Software suite contains a Batch Data Analysis Tool that utilizes macros to accelerate data analysis. Batch analysis saves time by analyzing abundant amounts of data created by the same protocol. To use batch analysis, simply turn on the macro capture feature, analyze the data, and save the macro. When additional data needs analyzing, simply apply the saved macro and the data is analyzed automatically.

**Automated Event Detection**

Clampfit Advanced Analysis Module, part of the pCLAMP 11 Software suite, has a flexible event detection engine that analyzes spontaneous and evoked action potentials and post-synaptic data. Events are detected by threshold crossing or a pattern-matching Template Search. Template Searches analyze spontaneous events like miniature synaptic EPSPs and IPSPs. Additionally, multiple event categories of events can be simultaneously detected. The integrated environment of Clampfit 11 Software links detected events in data to the spreadsheet and graph windows enabling quick contextual evaluation of the entire dataset.