New Feature

NEW: FULLY-INTEGRATED DYNAMIC CLAMP INTERFACE WITH UPDATE RATES UP TO 500kHz

FULLY INTEGRATED SINGLE- OR DUAL- HEADSTAGE PATCH CLAMP AMPLIFIER AND DATA ACQUISITION SYSTEM ENSURES QUICK AND EASY SETUP

ULTRA-HIGH BANDWIDTH ENABLES CHARACTERIZATION OF THE FASTEST SIGNALS OPTIMIZED FOR LOW-NOISE SINGLE-CHANNEL WHOLE-CELL PATCH CLAMP

FULL COMPUTER CONTROL PROVIDES AUTOMATED COMPENSATION OF ELECTRODE AND WHOLE-CELL CAPACITANCE FOR UTMOST PRECISION AND SIGNAL FIDELITY

VOLTAGE AND FASTFOLLOWER™ CURRENT CLAMP CAPABILITY FOR COMPLETE CHARACTERIZATION OF CELLS' ELECTRICAL ACTIVITY

dPATCH® LOW-NOISE ULTRA-FAST DIGITAL PATCH CLAMP AMPLIFIER SYSTEM

The **dPatch®** amplifier system was built around a simple idea: What if we built a cleansheet design that used the latest technology to make the next generation of patch clamp amplifiers? We hired the best hardware and software designers available in the industry, the same engineers who created the leading amplifiers already in the market. We asked them to design the best amplifier system possible, using the very latest in digital architecture, and pair it with a contemporary, easy-to-use, yet powerful software platform.

The resulting design represents a complete rethinking of how to best reduce noise and preserve signal to get the cleanest recordings possible, at a bandwidth that far exceeds anything else on the market. The **dPatch** amplifier system's digital architecture uses state-of-the-art methods in signal processing, such as field-programmable gate arrays (FPGAs) and Arm Core processors – technologies unavailable when the leading amplifiers in the market were designed well over 20 years ago. The processing power of this design FINALLY enables fully integrated dynamic clamp, as well as digital capacitance and resistance compensation. The included **SutterPatch®** software facilitates data acquisition, mangement and analysis with an intuitive and easy to learn interface.

Available in either a single- or dual-headstage configuration, the **dPatch** amplifier system's architecture makes swapping headstages, or adding a second one to a singleheadstage unit, a plug-and-play operation. The two headstages are independently configurable for either voltage clamp or FastFollower™ current clamp.

5 MHz sampling rate, up to 22 bits of resolution
One unique feature with **dPatch** is the headstage-based data sampling system. The signal from each headstage is continually digitized at 5 MHz. Output filtering has thirteen settings between 100 Hz and 1 MHz. A resolution of 18 bits is achieved at 1 MHz. For lower filter settings, automatic downsampling increases resolution while optimizing data rates. At a bandwidth setting of 1 kHz the **dPatch** system provides a signal resolution of better than 22 bits.

No active cooling required
Active cooling causes numerous problems that actually create more "noise" in the long run Active ooling in amplifier headstages use Peltier cells, which cool the electronics for slightly better performance, but generate considerable heat on the opposite side of the cell. The heat generated causes thermal drift which makes it almost impossible to stay patched while doing single-channel work.This is THE MOST COMMON source of what users perceive as "manipulator drift". As a company that makes micromanipulators, we are highly sensitive to the performance of the system within a complete electrophysiology rig.

Active cooling can help get a slightly better noise specification on paper, but in the real world the disadvantages far outweigh the slight gain in specsmanship. One of the development goals of the dPatch headstage was achieving a comparable noise performance at room temperature, without the need for a cooled headstage. In the two resistive feedback modes, the dPatch amplifier is even quieter than any of the competitor systems. In addition, the limited life expectancy of Peltier elements causes reliability concerns that we found unacceptable.

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MADE IN USA

10-2020

Built-in data acquisition system means no third-party hardware
Using a multiplexer-free design, the **dPatch** provides 8 fully differential analog input channels, 4 analog output channels, and 16 digital outputs (TTL). All I/O channels are sampled continuously (200 kHz for analog inputs, 250 kHz for analog and digital outputs) and available through the user interface.

SutterPatch® *Software*
The **dPatch** amplifier, in combination with **SutterPatch** software, has been engineered to automatically capture and store all amplifier settings, stimulus information and external experiment parameters, and associate them in time with the raw data traces. This includes all amplifier and acquisition settings, as well as timing and progress of the experiment. Fully integrated computer control of the amplifier stages means that the acquisition software is aware of the internal state of the amplifier and digitizer at all times and can track any changes that may occur. This is independent of whether a change is triggered automatically or initiated by the user.

• NEW FEATURE • *Dynamic Clamp*
The patented digital architecture of the **dPatch** amplifier system provides an ideal platform for dynamic clamp. The **dPatch** is powered by a system-on-chip which provides parallel processing across a Field Programmable Gate Array (FPGA) and two high-speed ARM core processors. Several sophisticated dynamic clamp models are implemented within this architecture. In each model, the update of the applied current values occurs without communication between the **dPatch** and a computer. Depending upon the complexity of the model, update rates of up to 500 kHz can be achieved.

Tracking of Other External Data
In addition to status changes in connected hardware that are automatically tracked, the researcher can manually trigger tags to document events like stimulus application using instruments not connected to the amplifier. Information about environmental parameters and a more detailed specification of sample properties can be recorded and stored with the raw data. A total of over 650 metadata attributes are supported. Examples include: animal species, genotype, date/time when a cell sample was prepared, recording solutions, pipette resistance, hardware properties, and detailed information about stimuli applied.

Data Visualization and Analysis
SutterPatch software has been designed to simplify the navigation and analysis of complex datasets. The scope window supports multiple view modes in both two-dimensional and an innovative three-dimensional display. The 3D view is particularly useful during assay development. Built on top of the latest version of the proven Igor Pro platform, **SutterPatch** combines native Igor Pro functionality with a wealth of features that are tailored to electrophysiology applications. Both the newcomer and the experienced user of patch clamp programs will quickly feel comfortable using **SutterPatch** software.

Application modules provide focused functionality for particular applications.

Currently Available:
- Event Detection Module: A deconvolution algorithm that excels at detecting miniature synaptic events even on a noisy background.
- Action Potential Analysis Module: Phase plane plot, timing and waveform statistics.
- Camera Module: An easy way to document the identity and condition of the recorded cell.

A Laboratory Workhorse
While a **dPatch®** system is ready for cutting-edge research, its feature set makes it immediately valuable in any lab setting.

- Three headstage feedback ranges for optimal whole-cell and single-channel recording
- Automated or manual compensation of electrode and whole-cell capacitance
- Series resistance compensation
- Simple cabling, quick and easy set-up
- High dynamic range of data acquisition module means no need for variable gain stages
- High speed of digitizer means no concern about sample rate

The **dPatch®** Integrated Digital Patch Clamp Amplifier is a computer-controlled single- or dual-headstage system for both single-channel and whole-cell recording applications.

Amplifier
- Hardware architecture enables all data conversion to be performed near the preparation, well away from known noise sources, such as power supplies and high-speed digital circuitry.
- Voltage clamp and FastFollower™ current clamp modes with smart switching between modes to avoid current artifacts
- Three choices of headstage feedback elements to optimize both single-channel and whole-cell recording

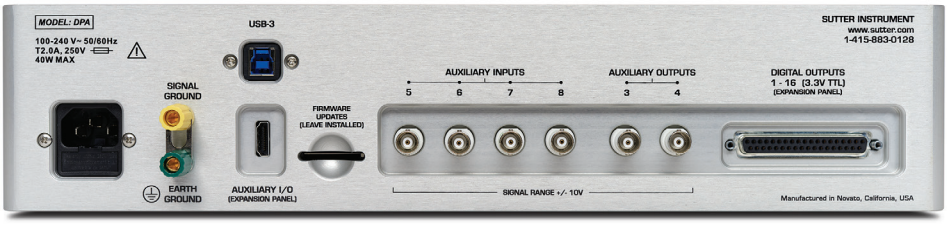
Feedback Element	Range	Analog Bandwidth	Noise 10 kHz BW	Pipette Capacitance Compensation Range	Series Resistance Range	Cell Capacitance Range
Capacitive	±20 nA	1 MHz	<0.22 pA_{RMS}	20 pF	N/A *	N/A *
500 MΩ	±20 nA	>250 kHz	<0.75 pA_{RMS}	20 pF	100 MΩ	100 pF
50 MΩ	±200 nA	>250 kHz	<2.40 pA_{RMS}	20 pF	10 MΩ	1000 pF

* Capacitive feedback range is optimized for single-channel voltage clamp recordings. Whole-cell compensation and current clamp mode are disabled with this range.

- Automatic compensation routines for pipette compensation and whole-cell compensation, and series resistance compensation
- Novel 2D matrix and triple-slider controls for manual compensation adjustment
- Series resistance prediction and correction independently programmable
- 8-pole Bessel filter 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50, 100, 250, 500, 1000 kHz
- Signal processing of filter output to increase resolution and reduce data file size
- Resolution over 22 bits at 1 kHz filter setting
- High dynamic range of analog to digital converters eliminates need for variable output gain stages
- Holding potential ±1000 mV
- Current clamp bridge compensation and pipette capacitance compensation
- Software lock-in amplifier with up to 20 kHz base frequency for high-resolution capacitance measurements

Data Acquisition
- Embedded data acquisition system eliminates the need for an external data acquisition board
  - 5 MHz sampling rate per headstage, up to 22-bits resolution
  - 8 Auxiliary analog inputs, 16-bit fully differential, ±10 V input, each continuously sampled at 200 kHz
  - 4 Analog outputs, 16-bits, ±10 V output each continuously updated at 250 kHz
  - 16 Digital outputs (TTL) each running at 250 kHz
  - Independent Trigger IN / Trigger OUT for synchronization of external instrumentation
- Single high-speed USB 3.0 connection controls data acquisition and amplifier settings
- Complex command waveforms
- Data acquisition can be initiated by an onboard microsecond clock or external (TTL) trigger

SutterPatch Software
- Built on the foundation of Igor Pro (WaveMetrics, Inc.)
- Paradigms and Routines provide complete experimental control
- Waveform Editor for easy creation of even the most complex stimulus patterns or user-defined templates
- Associated Metadata stores all relevant information regarding your experiment
- Comprehensive data analysis routines and publication-quality graphics
- Rapid-response online line-frequency reduction
- Runs on Windows or Macintosh OS X



Back panel of dPatch

Shown: DPATCH-PCH expansion panel

DPATCH SYSTEM

DPATCH Includes: dPatch® System with headstage and preamplifier, EH-Q170 pipette holder, model cell; SutterPatch® software suite with Igor Pro license, rack mounting hardware.

DPATCH-2 Includes: dPatch System with two headstages and preamplifiers, two EH-Q170 pipette holders, two model cells; SutterPatch® software suite with Igor Pro license, rack mounting hardware.

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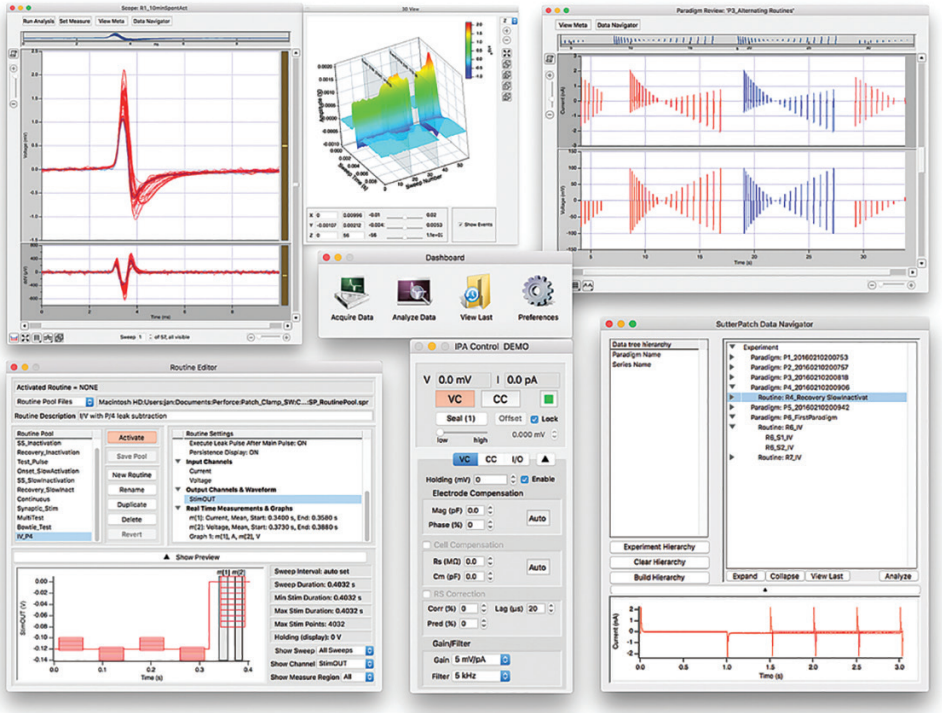

Screen shot of SutterPatch software

COMMON APPLICATIONS

- Single-channel recordings
- Auditory research and other rapidly changing signals
- Nanopore studies
- Tissue slice recordings
- Exo- and endocytosis measurements
- Cultured cell experiments
- Cell line studies from adherent or dispersed cells
- Optogenetics

Dynamic Clamp User Interface

The dynamic clamp user interface provides a powerful mechanism for loading dynamic clamp models. No expertise with scripting is required. Gate equations or Markov model transitions are simply entered as text and are interpreted by **SutterPatch®**. Individual dynamic clamp routines are saved in a pool and can be easily transferred between users. In addition, a number of models are provided to get users started, ranging from a simple leak conductance to a 12-state sodium channel.

dPatch® Ultra-fast Low-noise Digital Patch Clamp Amplifier System vs. Brand aX Low-noise Amplifier

Major Features

Specification	dPatch	Brand aX	Sutter Advantage
Computer Control	YES, fully digital design, controlled by SutterPatch® software	NO, analog knobs and buttons	State-of-the-art design
Data Acquisition	YES, high-speed computer interface integration, SutterPatch software included	NO, requires separate interface and software	12 analog I/O, 16 digital outs
Field Upgradable Software And Firmware	YES	NO	Easy upgrades to keep performance optimized
Built-in Software Lock-in Amplifier	YES	NO	High-resolution membrane capacitance measurements
Integrated Dynamic Clamp Capability	YES	NO	The fastest dynamic clamp for ion channel research
Support For Two Headstages	YES	NO	Headstages with full Plug-and-Play capability
Installation	Simple	Complicated	System is ready to run "out of the box" with a USB 3 computer connection. Grounding problems are minimized.

Whole Cell Voltage Clamp

Specification	dPatch	Brand aX	Sutter Advantage
Feedback Elements	500 MΩ, 50 MΩ	Same	
Noise, 500 MΩ	0.7 pA_{RMS} Range (10 kHz)	1.1 pA_{RMS}	36% lower noise
Noise, 50 MΩ Range (10 kHz)	2.3 pA_{RMS}	3.0 pA_{RMS}	23% lower noise
Bandwidth, Both FB Ranges	250 kHz	50 kHz	5X higher bandwidth
Output Filter Ranges	13 settings from 100 Hz to 1 MHz	5 settings from 1 kHz to 100 kHz	More settings, 10X higher bandwidth
Output Filter Type	8-pole Bessel	4-pole Bessel	8-Pole provides a lower-noise signal
Pipette Cap Compensation Range	20 pF	10 pF	2X compensation range

Single Channel Voltage Clamp

Specification	dPatch	Brand aX	Sutter Advantage
Feedback Element	1 pF / integrator	1 pF / integrator	
Bandwidth	1 MHz	100 kHz	10X higher bandwidth
Noise, 10 kHz	0.22 pA_{RMS}	0.13 pA_{RMS}	No active cooling*
Pipette Cap Compensation Range	20 pF	10 pF	2X compensation range

Current Clamp

Specification	dPatch	Brand aX	Sutter Advantage
Circuit Architecture	FastFollower™ true current clamp	Modified voltage clamp	Produces very accurate membrane voltage waveforms
10 to 90% Rise Time			
Rp = 1 MΩ	2 µs	15 µs	7.5X faster rise time
Rp = 10 MΩ	3 µs	20 µs	6.7X faster rise time
Mode Switching Voltage Clamp to Current Clamp	Special circuitry minimizes glitches	No glitch compensation	Near-zero glitch

* Active cooling causes numerous problems that actually create more "noise" in the long run. The heat generated by Peltier cells cause thermal drift in manipulators, making it almost impossible to stay patched while doing single-channel work. As a company that makes micromanipulators, we are highly sensitive to the performance of the system within a complete electrophysiology rig. Active cooling can help get a slightly better noise specification on paper, but in the real world the disadvantages far outweigh the slight gain in specs-manship. In addition, the limited life expectancy of Peltier elements causes reliability concerns that we found unacceptable.

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