EPC 10 USB

Patch Clamp Amplifier family

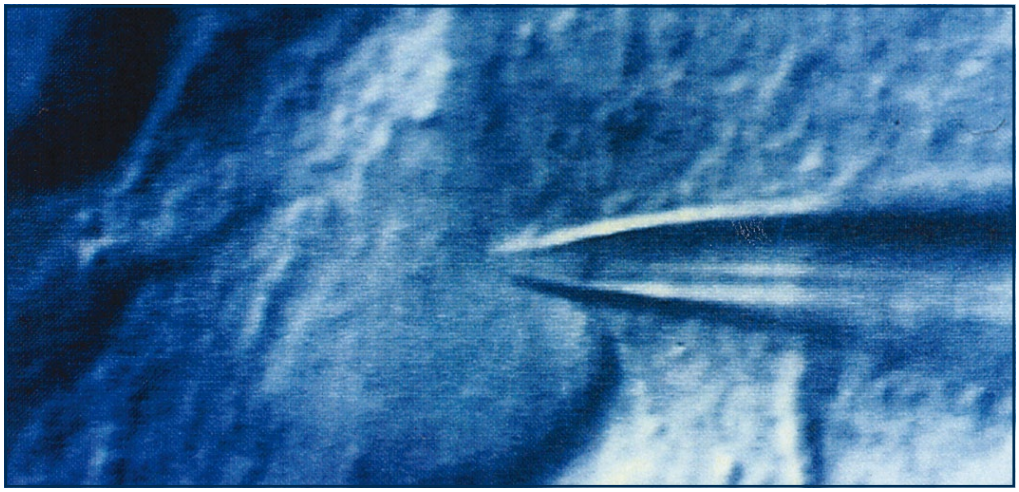
EPC 10 USB Single

EPC 10 USB Double

EPC 10 USB Triple

EPC 10 USB Quadro

HEKA provides the finest instruments today
to achieve the needed progress of tomorrow…



Introduction

HEKA is pleased to release the newest family of fully computer controlled patch clamp amplifiers. **The EPC 10 USB** amplifiers are available with one (EPC 10 USB), two (EPC 10 USB Double), three (EPC 10 USB Triple) or four (EPC 10 USB Quadro) amplifiers. The EPC 10 USB patch clamp amplifiers are successors of the revolutionary EPC 9 patch clamp amplifiers, which were first introduced in 1990[1)2)3)], and the well known EPC 10 patch clamp amplifiers, which replaced the EPC 9's in 2002.
This hardware product line is fully integrated with HEKA's new LIH 8+8 AD/DA interface. The built-in interface utilizes the latest USB 2.0 and high speed processing technologies without the need for a peripheral PCI card. The advanced integration of the EPC 10 USB with the interface and software minimizes total recording noise, eliminates compatibility problems and reduces additional equipment expenses and set-up time.
The digital control of all amplifier functions has been designed with two advantages in mind. Firstly, if a computer controls the functions of the amplifier, then the data acquisition program can access and store variables that describe all of the settings during an experiment. Secondly, computer control allows a number of operations to be automated. These include automatic switching (e.g, switching between the settings for establishing a seal or those for single channel recording) and also the automatic adjustment of capacitance transients cancellation and series resistance compensation. In fact, digital control of every adjustable parameter in the amplifier circuitry is implemented, including the calibration adjustments.

Applications

The EPC 10 USB family of amplifiers can be used, for example, for any of the following applications…

- Low Noise Single Channel Recordings
- Low Noise Whole-cell patch clamp recordings: voltage clamp and current clamp/LFVC
- Measurements of fast action potentials (AP), fast switching between voltage and current clamp and vice versa
- Loose Patch Recordings[4)]
- Intracellular voltage recordings with high resistance electrodes
- Field potential recordings
- Recordings from artificial membranes (Bilayer Recrodings) and nanopores
- Study Synaptic Transmission by simultaneous stimulation/recording from multiple cells (e.g. pre- and post-synaptic cells)
- Study of Long Term Potentiation (LTP) and Long Term Depression (LTD)
- Study Exocytosis/Endocytosis or Synaptic Transmission by
  - Measurement of whole-cell membrane capacitance
  - Measurement of on-cell membrane capacitance
  - Detection of released substances (amperometry with e.g. carbon fiber electrodes)
  - Detection of release substances under a patch (patch amperometry)
  - Combined membrane capacitance with amperometry (using EPC 10 USB Double)
  - Combined patch amperometry and on-cell capacitance measurements (using EPC 10 USB Double)
- All above mentioned methods can be combined with photometric determination of e.g. the internal calcium ion concentration.

Models and Features

EPC 10 USB Single Patch Clamp Amplifier

The EPC 10 is a complete data acquisition system, which can be used with HEKA's PATCHMASTER or TIDA software. A DLL (dynamic link library) is available to allow access of the system from a custom written application. The EPC 10 USB patch clamp amplifier, combined with a computer and PATCHMASTER or TIDA software is equivalent to a fully equipped setup, which includes a patch clamp amplifier, a digital storage oscilloscope, a variable analog filter, a sophisticated pulse generator, and a fully featured data acquisition and analysis system.

Common Features

- The only really digitally controlled patch clamp amplifier with built-in AD/DA converter interface is perfectly software controlled. Works on Mac and Windows platform. Can be used with PATCH MASTER and PATCHMASTER PRO on Windows and Mac, and with TIDA on Windows.
- Integration with the optimized low noise LIH 8+8 AD/DA interface
- The amplifier/digitizer requires only one USB 2.0 interface. Data acquisition and amplifier are controlled through a single fast USB 2.0 port. The amplifier is completely and perfectly controlled by the software. Configurable Hot Keys allow a direct access to all amplifier settings. No additional knobs and switches are required.
- Self-testing and self-calibration functions allow easy test and calibration of the patch clamp amplifier by the user in their own laboratory. This is of very importance since electronic parts will alter with time. Therefore, manually calibrated amplifiers have to be sent in for re-calibration in regular intervals whereas digitally controlled amplifiers such as EPC 10 USB type amplifiers can be easily re-calibrated by the user.
- The headstage can be replaced and calibrated by the user. No shipment to the service center is required for re-calibration of the amplifier. The replaced headstage works with the same quality as a complete new instrument.
- Optimal grounding configuration. The factory-site integration of the DA/AD interface and corresponding internal shielding/grounding provide an optimal grounding and noise configuration for all measuring configurations and eliminates compatibility problems. No external BNC connections are required.
- CSlow compensation in high gain range. The amplifier features CSlow compensation in high gain range (50 GOhm feedback resistor) for low noise whole-cell measurements.
- Ultra slim-line headstage for recording single-channel, whole cell and loose patch currents
- Resistor switching headstage with three gain ranges that can be switched during the experiment
- True Current Clamp mode
- Mode to preserve the membrane potential at a desired level during current clamp measurements. The so-called „Low Frequency Voltage Clamp" (LFVC) mode automatically injects an appropriate amount of current to preserve the membrane potential at a desired level during current clamp measurements.
- Gentle Switch option to CC mode (injection current is equal to Imon in VC)
- Automatic Capacitance neutralization (C-Fast and C-Slow)
- Capacitance tracking
- Hardware leak compensation for non-voltage gated channels
- Digital outputs & telegraphing inputs
- Integration of hardware and software eliminates compatibility problems
- True noise measurements from 100 Hz to 15 kHz
- Built-in sound capabilities
- Can be extended with an additional LIH 8+8 interface
- Digital I/O connector for EPC 8 or TIB 14S
- All amplifier settings and parameters at any given time are stored with the data
- EPC DLL (dynamic link library) is available to control the amplifier from your own applications (Windows)

EPC 10 USB Double, Triple, Quadro Patch Clamp Amplifier

EPC 10 USB Double

The EPC 10 USB Double, Triple and Quadro amplifiers are the perfect instruments for performing multiple patch/cell experiments. Although two, three or four amplifiers are combined in a single housing, along with the AD/DA interface, each amplifier is completely independent. The amplifiers and headstages are clearly identified, thus, the user can immediately assign the amplifiers to particular patched cells. The amplifiers can be stimulated simultaneously with resulting simultaneous data acquisition with the PATCHMASTER software that can acquire data from up to 16 channels. Current and voltage signals from all of the amplifiers can be recorded, displayed and analyzed online.

The EPC 10 USB Double, Triple and Quadro amplifiers are also economical solutions in comparison with the combination of several individual instruments. They also have advantages over multiple external amplifiers in terms of optimized noise performance, grounding, data acquisition and storage, convenience and ease of integration.

EPC 10 USB Quadro

EPC 10/n USB Additional Features

- Each amplifier section is a completely independent circuit board with headstage
- The amplifiers can be stimulated independently and simultaneously acquired with PATCHMASTER software

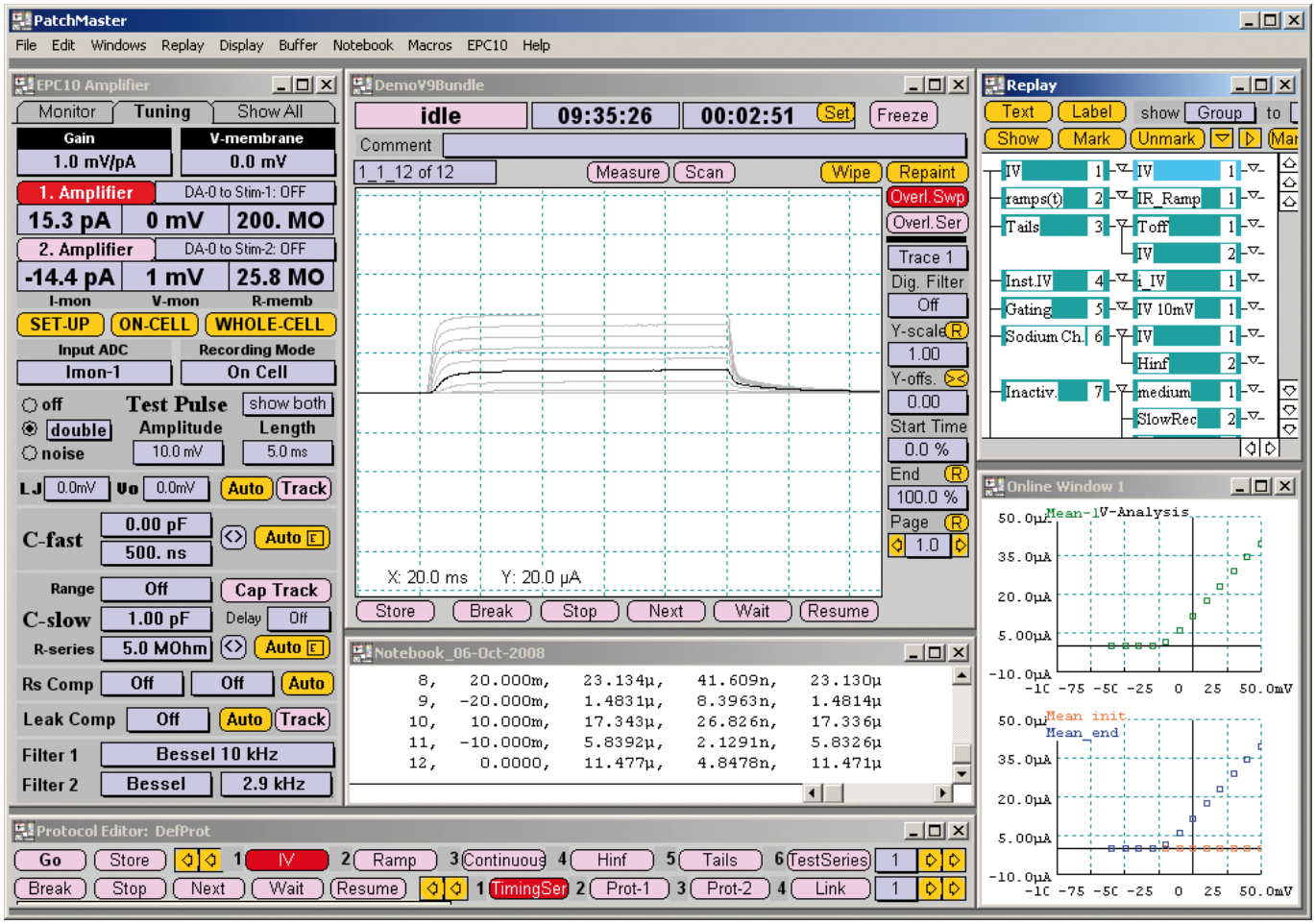
Product Content

The **EPC 10 USB** Patch Clamp Amplifier includes:	The **EPC 10 USB Double** Patch Clamp Amplifier includes:	The **EPC 10 USB Triple** Patch Clamp Amplifier includes:	The **EPC 10 USB Quadro** Patch Clamp Amplifier includes:
• One amplifier	• Two amplifiers	• Three amplifiers	• Four amplifiers
• One headstage	• Two headstages	• Three headstages	• Four headstages
• One interface board	• One interface board	• One interface board	• One interface board
• One pipette holder	• Two pipette holders	• Three pipette holders	• Four pipette holders
• One model circuit	• One model circuit	• One model circuit	• One model circuit
• One printed manual	• One printed manual	• One printed manual	• One printed manual
• Cables to connect to the computer and power line	• Cables to connect to the computer and power line	• Cables to connect to the computer and power line	• Cables to connect to the computer and power line
Item No.: EPC 10 USB	*Item No.: EPC 10 USB Double*	*Item No.: EPC 10 USB Triple*	*Item No.: EPC 10 USB Quadro*

Software Control Options

PATCHMASTER

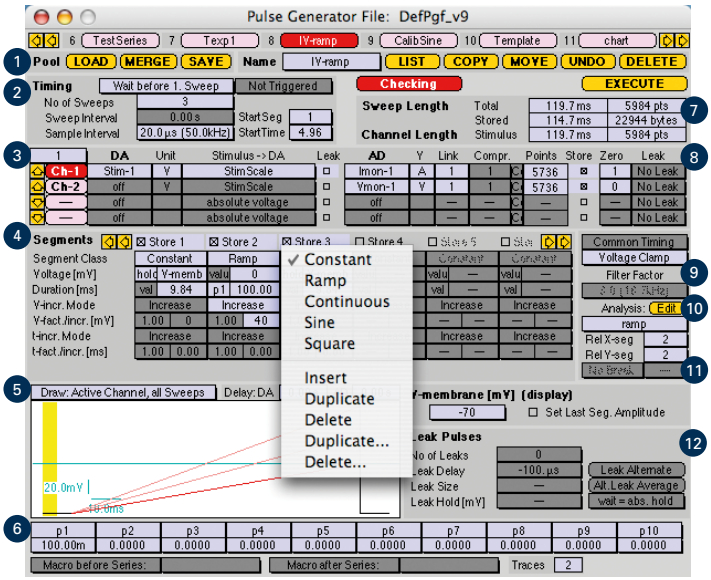
The EPC 10 USB family of amplifiers can be controlled with PATCHMASTER software on either Windows (2000/XP/Vista) or Mac platform. PATCHMASTER is a multi-channel stimulation/acquisition and control software. For more details please refer to the PATCHMASTER brochure.



Complete amplifier control Each amplifier control can be accessed through the software and many task such as compensation of capacity values can be automated and executed on a single mouse click or button press.
Amplifier parameter can be read and set from the software allowing to setup sophisticated control loops.

Sophisticated design of your stimulation protocols. The Pulse Generator window within PATCHMASTER defines all of the parameters for data acquisition, waveform generation and external device control. A Pulse Generator File (PGF) is comprised of any number of predefined sequences

1. **Sequence Pool:** A paging bar that loads, saves, copies etc.. the pool of available stimulation sequences.
2. **Timing:** Specification of the number of sweeps, sweep interval and sampling rate.
3. **DA-channels:** Multiple DA channels and digital trigger lines can be selected for output.
4. **Segments:** The stimulation pattern consists of an arbitrary number of segments with each segment having a defined type, duration, amplitude and increment/decrement factors.
5. **Template Preview:** Graphical display of the stimulation template.
6. **PGF-Parameters:** Global variables can be used for sequence editing.



7. **Sweep Length:** Display of the stimulus length and amount of acquired data.
8. **AD-channels:** Up to 16 channels can be acquired simultaneously. Data compression and store/non-store flags on individual traces can reduce the required data storage capacity.
9. **Filter Factor:** Input filter is set automatically with respect to the sampling rate.
10. **Analysis:** Direct link of the PGF to the corresponding analysis method.
11. **Break Condition:** User control of AD channel acquisition. Stopps data acquisition if one condition becomes true.
12. **Leak:** Determines various parameters of the leak pulses for p/n subtraction.

Entire experimental procedures at the touch of a button. Simple or complex experimental procedures can be designed, stored and executed from within the protocol editor of PATCHMASTER.
The idea is to generate a list of events or tasks, which comprise your complete experiment, and can be executed automatically. Within a procedure, feedback from external inputs, amplifier controls, online analysis results or user inputs and experimental parameters can be adjusted. A protocol can be started / called from another protocol. Various tasks such as repeat loops, input queries or conditional statements allow for the generation of complex interactive processes.
Scientists that are asking for complex, precisely timed experimental protocols will appreciate the vast array of features within the protocol editor. The high degree of automation options will increase efficiency and minimize experimental errors.

Software Control Options

EPCMASTER

In situations where the EPC 10 USB amplifier is being used in conjunction with a custom data acquisition system, HEKA provides the software EPCMASTER for control of the amplifier functions. Amplifier functions can be set from another application by use of the Batch Control interface of the EPCMASTER software. EPCMASTER is free of charge.

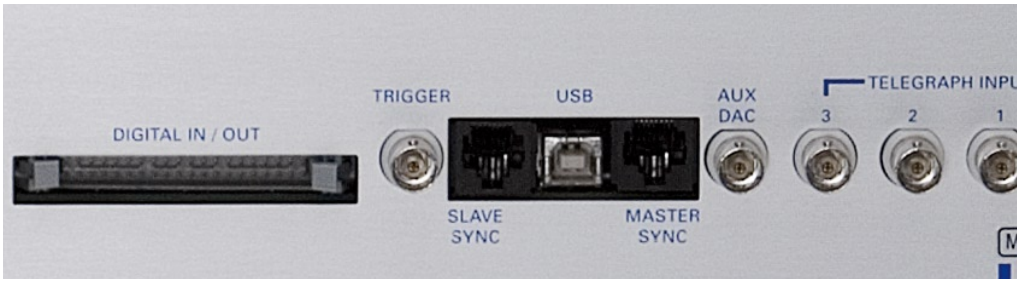
EPC.DLL

To integrate the EPC 10 USB amplifier and data acquisition system in customized software on Windows, HEKA provides an EPC.DLL (dynamic link library).

Extending an EPC 10 USB

with an LIH 8+8

The number of input and output channels available on the front panel of the EPC 10 USB family of amplifiers can be extended by combining an EPC 10 USB amplifier with an additional LIH 8+8 interface. This may be especially useful when using an EPC 10/n USB amplifier in which the number of available outputs is decreased because of internal usage to stimulate the additional amplifiers.



with a second EPC 10 USB

The number of recording channels and the number of amplifiers can be increased by connecting two or more EPC 10 USB amplifiers. On the rear panel of the EPC 10 USB there are "Slave Sync" and "Master Sync" USB connections. Multiple EPC 10 USB amplifiers can be chain connected in such a way to create 8 or 16-channel parallel patch clamp amplifiers. This daisy-chain connection can be applied to either the single, double, triple and quadro versions of the amplifier.

For example, a 8-channel parallel patch clamp amplifier can be configured by connecting two EPC 10 USB Quadros. These 8 independent patch clamp amplifiers can be controlled by one copy of PATCHMASTER. Expandability to a 16-channel parallel patch clamp amplifier can be done by connecting four EPC 10 USB Quadros. In this case the amplifiers are controlled by two copies of PATCHMASTER that are synchronized and data acquisition can be automatically transfer to a single data file.

with an EPS Probe Selector

A headstage multiplexing devices called the Probe Selector can also be used with the EPC 10 USB family of amplifiers. The Probe Selector is available with up to 16 heastages. The headstage mulitplexing device can turn a single EPC 10 USB patch clamp amplifier, e.g. into a sixteen channel serial patch clamp device. Each amplifier of an EPC 10/n USB can be extended by a single Probe Selector, resulting in systems with 32, 48 or 64 channels. Alternatively, a single EPS Probe Selector can be connected to an EPC 10 USB Double or EPC 10 USB Quadro patch clamp amplifier. In this configuration the EPC 10 USB Double is converted into a 2 by 8 - channel amplifier, meaning that two channels (parallel) are mulitplexed 8 times. The EPC 10 USB Quadro would be turned into a 4 by 4 – channel amplifier, meaning that four channels (parallel) are mulitplexed 4 times. The active probe(s) of the Probe Selector behaves like a headstage connected directly to the EPC 10 USB amplifier. "Non-active" probes are held at its individual holding potentials in medium gain range.

with a TIB 14S Trigger Interface

In order to output 14 digital channels via BNC connectors, a TIB 14S trigger interface can be connected to the EPC 10 USB via the Digital I/O connector. The TIB 14S allows either manual or software controlled switching of the digital lines. The TIB 14S can also drive magnetic valves directly.

References

1) Electronic Design of the Patch Clamp. F.J.Sigworth. Single-Channel Recording, Second Edition, edited by Bert Sackmann and Erwin Neher. Plenum Press, New York, (1995) 95-127.

2) Design of the EPC-9, a computer–controlled patch-clamp amplifier. 1. Hardware, F.J.Sigworth, Journal of Neuroscience Methods 56 (1995) 195-202.

3) Design of the EPC-9, a computer–controlled patch-clamp amplifier. 2. Hardware, F.J.Sigworth, H.Affolter, E.Neher, Journal of Neuroscience Methods 56 (1995) 203-215.

4) Loose Patch Recording. W. Stühmer. Practical Electrophysiologica Methods, edited by H. Kettenmann and R. Grantyn. Wiley-Liss, New York, (1992) 271-273.

Technical Specifications

General

Number of Amplifiers/Headstages

EPC 10 USB Single:	1
EPC 10 USB Double:	2
EPC 10 USB Triple:	3
EPC 10 USB Quadro:	4

Amplifier Control
Fully software controlled patch clamp amplifier featuring e.g. direct access to all amplifier settings, automatic calibration and self testing/diagnosis procedures.

Host Interface USB 2.0

Dimensions Main Unit

	Single	Double	Triple	Quadro
Depth x Width	31.1 x 48.3 cm 12.3 x 19.0 inch			
Height	14.5 cm 5.7 inch	18.0 cm 7.1 inch	26.9 cm 10.6 inch	
	mounts in a 19" rack			

Weight Main Unit

Single	Double	Triple	Quadro
11.4 kg 24.8 lbs	12.2 kg 16.5 lbs	15.3 kg 33.3 lbs	16.5 kg 38.9 lbs

Dimensions Headstage
D x W x H: (90 x 17 x 14.5) mm / (3.54 x 0.67 x 0.57) inch

Power Supply
Power requirements are 125 Watt. The logic controlled power supply automatically switches the voltage range. It operates in the ranges 100V to 120V and 200V to 240V at line frequencies of 50 or 60 Hz. A shielded transformer minimizes noise pickup from power line frequencies.

Ground Lines
A Signal ground is accessible via a Banana plug on the front panel of the main unit and via a connector pin on the headstage. In case of EPC 10 Double, Triple and Quadro, all amplifiers share the same ground.
A Chassis ground is accessible via a Banana plug on the front panel of the main unit. Chassis and Signal ground are connected via a 10 MOhm resistor.

Voltage Clamp Mode

Current Measuring Resistors
The headstage provides three feedback resistors. The gain ranges can be switched during the experiment.

low gain range:	50 GOhm,	± 200 pA current range
medium gain range:	500 MOhm,	± 20 nA current range
high gain range:	5 MOhm,	± 2 µA current range

Current Gain Settings

low gain range:	0.005, 0.01, 0.02, 0.05, 0.1, 0.2 mV/pA
medium gain range:	0.5, 1, 2, 5, 10, 20 mV/pA
high gain range:	50, 100, 200, 500, 1000, 2000 mV/pA

Input Capacitance < 1 pF

Noise Performance
Measured with open input via external 8-pole Bessel filter.
Medium gain range:

up to 1 kHz:	appr. 180 fA rms (theoretical limit)
up to 3 kHz:	appr. 320 fA rms (theoretical limit)
up to 10 kHz:	appr. 580 fA rms

High gain range:

up to 1 kHz:	< 30 fA rms
up to 3 kHz:	< 85 fA rms
up to 10 kHz:	< 350 fA rms

Bandwidth
100 kHz (low and medium range), > 60 kHz (high gain range)

Current Filter
Filter 1 is a 6-pole Bessel pre-filter with 10 kHz, 30 kHz, 100 kHz, and HQ 30 kHz. The EPC 10 USB Single, Double, and Triple allow to directly sample the current signal of Filter 1 via the MUX channel. Filter 2 is a 4-pole filter with 100 Hz to 15 kHz bandwidth with selectable Bessel or Butterworth characteristics. Filter 2 is usable in series with Filter 1 or as separate filter for external signals.

Holding Potential
Software controlled holding within a ± 1000 mV range.

External Stimulus Input (VC)
Via a BNC connector at the front panel an external stimulus input can be added to the internal set holding potential. An External Stim Scaling circuit allows scaling of the external stimulus with a factor in the range of – 1.0 to + 1.0.

Compensations in Voltage Clamp Mode

Pipette Offset Potential Compensation
Automatic or manual adjustment of the offset potential in the range ± 200 mV.

Injection Capacitors
The C-Fast compensation signal is injected via a 1 pF capacitor. The C-Slow compensation signals are injected via a 10 pF capacitor in medium and low gain and via a 1 pF capacitor in high gain range.

C-Fast Compensation
Automatic or manual compensation in all gain ranges. 0 to 15 pF, 0 to 8 µs tau (calibrated)

C-Slow Compensation
Automatic or manual compensation in all gain ranges.
0.2 to 1000 pF in low and medium range, 0.2 to 100 pF in high range.
Rs range 1 MOhm to 1 GOhm.

Synchronous C-Slow Compensation
The EPC 10 USB Double and Triple provide the option for synchronous C-Slow compensation pulses on multiple cells. This is essential for using the C-Slow compensation when measuring on multiple electrically connected cell.

Series Resistance Compensation
Maximal compensation is 95% with the optimal setting being dependent on the cell capacitance.
Equivalent time constants: 2 µs, 10 µs, 100 µs
Ranges: 1 to 1000 MOhm (medium range), 0.1 to 10 MOhm (low range)

Hardware Leak Subtraction
Linear leak can be either subtracted automatically or manually.
Injection time constant: 100 µs
Ranges: 0 to 2 nS (high range), 0 to 200 nS (medium range), 0 to 20 µs (low range)

Software Leak Subtraction
A versatile p/n leak subtraction is provided in combination with the PATCHMASTER software.

Other VC Features

Zap Pulse
Provided by the PATCHMASTER software. The amplitude (up to ± 1V) and duration is programmable.

Audio Resistance Monitor
A 3.5 mm jack is provided at the front panel for connecting phones or speakers.
Volume and Resistance/Frequency ratio can be adjusted by the PATCHMASTER software. Frequency range: 200 Hz to 4 kHz.

Current Clamp Mode

Current Injection
Three current injection gains are selectable:
0,1 pA/mV; range ± 1 nA
1 pA/mV, range ± 10 nA
10 pA/mV; range ± 100 nA

Voltage Gain
Two gain ranges are selectable:
V-mon x 10, range ± 1000 mV
V-mon x 100, range ± 100 mV

External Stim Input (CC)
Via a BNC connector at the front panel an external stimulus input can be added to the internally set holding current. The scaling factor is determined by the selected current injection gain.

C-Fast in CC Mode
C-Fast is active in current clamp mode to allow voltage recordings at high bandwidth.

Bridge Mode
The voltage drop across the pipette resistance can be compensated.

Low Frequency Voltage Clamp (LFVC)
Automatic current tracking readjusts the holding current to fix any slow voltage drift while in current clamp mode.

Gentle Switch
When switching from voltage to current clamp, the holding current is automatically set to the I-mon in voltage clamp mode.

Fast Mode Switching
The PATCHMASTER software allows to rapidly switch between current and voltage clamp mode and vice versa during data acquisition.

DA/AD Converter

Stimulation	Number of DA converters:	4
	Settling Time:	1 µs
	DA output voltage range:	± 10 V
	Number of AD converters:	2
	DA/AD resolution:	16 bit
	Fastest Sampling Rate:	
	2 channels	200 kHz
	8 channels	50 kHz
Free DA channels:	EPC 10 USB Single:	3
	EPC 10 USB Double:	2
	EPC 10 USB Triple:	1
	EPC 10 USB Quadro:	0
Free AD channels:	EPC 10 USB Single:	5
	EPC 10 USB Double:	3
	EPC 10 USB Triple:	1
	EPC 10 USB Quadro:	0

Telegraphing Inputs
Four 12 bit asynchronous AD channels allow acquisition of telegraphing signal from other amplifiers.

Digital Input/Output
Digital I/O: 16 digital in and 16 digital out channels are provided on a 40 pin male connector on the rear panel.
Digital In: 16 channels provided at the Digital In connector on the rear panel.
Digital Out: 16 channels provided at the Digital Out connector on the rear panel, three of them are also provided via BNC on the front panel.
Trigger In: Via 1 BNC connector on the front panel data acquisition can be triggered externally.

Master/Slave Sync
2 CAT5 connectors for synchronization of a second amplifier/interface system are provided at the rear panel.

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