Axon™ Axopatch™ 200B Microelectrode Amplifier Specifications

Unless otherwise noted: T_A = 20°C, 1 hour warm-up time.

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

0.1 mV/pA (β = 0.1) Whole-Cell mode

Feedback element:

Patch	1 pF
Whole Cell	β = 1, 500 MΩ in parallel with 1 pF
Whole Cell	β = 0.1, 50 MΩ in parallel with 1 pF

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:

Patch	none
Whole Cell	β = 1: 5 pF
Whole Cell	β = 0.1: 50 pF

Case: Connected to ground. Case jack mates to 1 mm plugs.

Bandwidth: Test signal applied via Speed Test input

Internal: 140 kHz patch mode
70 kHz whole-cell mode

Max. external: 100 kHz (limited to output filter)

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

Max. Instrument Noise: Without Holder			
	Patch	Whole Cell	Whole Cell
Line Frequency and Harmonics	β = 1 0.005 pA_{p-p}	β = 1 0.005 pA_{p-p}	β = 0.1 0.005 pA_{p-p}
0.1–100 Hz	0.030 pA_{p-p}	0.50 pA_{p-p}	1.6 pA_{p-p}
0.1–1 kHz	0.015 pA_{rms}	0.25 pA_{rms}	0.75 pA_{rms}
0.1–5 kHz	0.060 pA_{rms}	0.65 pA_{rms}	1.65 pA_{rms}
0.1–10 kHz	0.130 pA_{rms}	1.10 pA_{rms}	3.0 pA_{rms}
Max. Instrument Noise: With Holder			
0.1–10 kHz	0.145 pA_{rms}	1.10 pA_{rms}	3.0 pA_{rms}

Reset Characteristics (Patch mode only)

Total reset time: 50 µs ±10%

Time between resets (T_{BR}):
For DC currents: $T_{BR} = 10 / (I_{DC} - I_{BIAS})$ where I_{DC} and I_{BIAS} are in pA and T_{BR} 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):

100 Hz	±0.25 pA
1 kHz	±0.5 pA
10 kHz	±2 pA

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 R_s 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.

			10–90% rise time (overshoot)	10–90% rise time (overshoot)
R_p	R_m	C_m	I-Clamp Normal	I-Clamp Fast
1 MΩ	0 MΩ	0 pF	15 µs (10%)	N/A
1 MΩ	500 MΩ	33 pF	350 µs (0%)	N/A
10 MΩ	0 MΩ	0 pF	200 µs (20%)	20 µs (< 1%)
10 MΩ	500 MΩ	33 pF	250 µs (10%)	10 µs (< 1%)
50 MΩ	500 MΩ	33 pF	500 µs (30%)	150 µs (< 1%)

Capacitance Compensation

Pipette Capacitance	
Fast τ	0.2–2 µs
Fast Magnitude	0–10 pF
Slow τ	0.1–10 ms
Slow Magnitude	0–1 pF

These controls are used to charge pipette capacitance. In I-Clamp modes they act as a negative capacitance.

	β = 1	β = 0.1
Whole-Cell Capacitance	0.3–100 pF	3–1000 pF
Series Resistance	0–100 MΩ	0–100 MΩ

These controls are used to charge membrane capacitance in whole-cell V-Clamp. For Patch mode, whole-cell capacitance is not operative. In I-Clamp modes only the Series Resistance control is operative. The whole-cell capacitance control places an analog voltage proportional to setting on Cell Capacitance Telegraph Output.

Series Resistance Compensation

% Prediction: OFF, 0-100%. Acts with Whole-Cell Parameters to speed up charging of the membrane. Maximum achievable % Prediction is limited by the magnitude of the voltage step.

% Correction: OFF, 0-100%. Acts with Series Resistance setting to reduce series resistance errors and to speed up response to ionic currents.

Lag: 1–100 µs. Cuts high-frequency response of series-resistance correction circuit to enable a higher Correction setting.

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 1 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

Sensitivity:

	V-Clamp	I-Clamp		Track	I = 0
		β = 1	β = 0.1		
Front input	20 mV/V	2 nA/V	20 nA/V	disabled	disabled
Rear input	100 mV/V	2 nA/V	20 nA/V	disabled	disabled

Input impedance: 10 kΩ. Inputs may be connected in parallel to increase sensitivity.

Holding command: Ten-turn potentiometer with dial. Polarity switch. Value can be previewed on meter.

V-Clamp mode:

	V-Clamp	I-Clamp		Track	I = 0
		β = 1	β = 0.1		
Toggle x1	±200 mV	±2 nA	±20 nA	disabled	disabled
Toggle x5	±1 V	±10 nA	±100 nA	disabled	disabled

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 V_{DC} 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.

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.

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 V_m 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 V_{p-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 (αβ mV/pA) when in V-Clamp or Track modes. Output is V_m (α mV/mV) when in I-Clamp mode. BNCs on front and rear panels are identical.

I: Pipette current. Rear-panel switched gain of either β mV/pA or 100 β mV/pA; fixed filter: 10 kHz 3-pole Bessel. Output does not benefit from sample and hold pedestal compensation.

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

Output Controls

Output gain: 10 values from 0.5-500. Affects Scaled Output only. Selected value sets 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 β MΩ to 200 GΩ x β.

Telegraph Outputs

Gain: Takes α and β gain factors into account.

I (mV/pA)	0.05‡	0.1‡	0.2‡	0.5	1	2	5	10	20	50	100†	200†	500†
V_m (mV/mV)				0.5	1	2	5	10	20	50	100	200	500
Telegraph Output (V)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5

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

Frequency:

Filter Setting (kHz)	1	2	5	10	100
Telegraph Output (V)	2	4	6	8	10

Mode:

	Track	V-Clamp	I=0	I-Clamp Normal	I-Clamp Fast
Scaled Output	I	I	V_m	V_m	V_m
Telegraph (V)	4	6	3	2	1

Cell capacitance (Telegraph output):
0 to +10 V, proportional to setting 0-100 pF (for β = 1; 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_{RMS}) 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

Unit is supplied with two model cell assemblies, the PATCH-1U and the MCB-1U 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):	1.8 (H) x 1.9 (W) x 10.5 (D)
Mounting plate (in.):	0.25 (H) x 2.0 (W) x 2.5 (D)
Mounting plate (cm):	0.6 (H) x 5.0 (W) x 6.2 (D)
Communications:	Analog and digital BNC
Rack use:	Standard 19" rack-mount (2U) with handles
Benchtop use:	Bayonet feet
Power:	85–264 VAC (110–340 VDC) 50–60 Hz, 30 watts (max.)
Fuse:	0.5 A slow (5 x 20 mm)
Line filter:	RFI filter included
Line cord:	Shielded line cord provided
Safety:	CE marking (Conformité Européene)

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